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Low Loss Transmission Circular Polarizer for KU Band Application

Farman Ali Mangi[1], Nafessa Shahani[2], Deedar Ali Jamro[1]

Abstract:

Low loss transmission circular polarizer is proposed for Ku band applications. The designed structure consists of two closely cross metallic strips which are based on FSS for 15.25 GHz and 15.28 GHz applications. The right hand circular polarization (RHCP) and left handed circular polarization (LHCP) are obtained at 15.25 GHz and at 15.28 GHz. The transmission loss through polarizer is important issue for high frequency applications. Due to transmission loss, new techniques are required to reduce the transmission loss of transmitted wave and achieve pure circular polarization. Meanwhile, low loss transmission has been achieved by using dual layer of strips to obtain perfect circular polarization at certain mentioned resonant frequencies. Theoretically, it is found that the outgoing waves through polarizer are perfect circular polarization at the distinct frequency ranges.

Keywords: *Polarizer; Circular Polarization; Frequency selective surface; Quarter wave plate; Metamaterial.*

1. Introduction

In modern microwave communication, circular polarization has received great interest in recent years. Precise, manipulation and detection of circular polarization of electromagnetic waves is important in modern technology. Artificially generating circular polarization is significantly more challenging in microwave communication technology. For instance, circular polarization is widely used in microwave communication and satellite communication systems. In addition, the CP achieves reflection effect, atmospheric absorption and lower susceptibility and intrinsically lower cross polarization discrimination.

An electronically steerable CP antenna array is more efficient for the inter-aircraft communication in terms of mobile nodes and wireless communication. The common application of antenna arrays is complex due to reduced level of practically-achievable output for extended millimetre wave communication network [1]. The CP antenna array approach was introduced for the use of a linearly polarised antenna array and electromagnetically coupled polarising wave plate. Dielectric polarisers [2], meander-line [3-5] and grid-plate [6] polarisers have been proposed to convert linear polarised electromagnetic waves to circular. CP antenna array is the combination of individual antenna elements which realize the directivity requirement and gain for the long distance [7-

[1] Department of Physics, Shah Abdul Latif University Khairpur, Sindh, Pakistan
[2] Institute of Chemistry, Shah Abdul Latif University Khairpur, Sindh, Pakistan
Corresponding Email: farman.mangi@salu.edu.pk

8]. In previous research contribution, the transmission type circular polarizers were proposed, such as U-shape split ring resonators, metallic helices, parallel plates, twisted Q-shaped metasurface, split ring resonator [9-10]. The four patch antennas were selected to produce 90^o phase shift and [11] introduces an elliptical CP dielectric resonator antenna array. In [12, 13], the thin dual-band polarizer was designed for satellite applications and meta-device with different functionalities is integrated.

The several known CP antennas composed of different multi-pot feed networks and radiation elements which makes them inefficient for practical application. The end fire antenna array are introduced to date [14, 15] which are constructed of seamless integration with linearly polarized. Polarization state of electromagnetic waves affect our daily life in order to consumer products to high technology applications [16]. The characteristics of a non-isotropic transparent material based on the electromagnetic waves incident upon a birefringent material.

If E field converted in two orthogonal components of $_{Ex}$ and E_y having same amplitude, the phase shift of any one component will result in circular polarization and satisfy the phase shift 90^o is known as quarter wave plate. The intensity of the incident electromagnetic wave does not change after propagating through a wave plate (only the polarisation state is changed). Wave plates are mostly considered as linearly birefringent, which means that the index of refraction differs along the two principal axes, which affects the phase shift of the orthogonal components differently [17].

Quarter wave plate possesses intriguing property to convert linear-to-circularly polarized waves when it is twisted at 45^o to the impinging polarizing plane. The unique characteristics of quarter wave plate is to change EM waves from linear-to-circularly polarized states. Most often, the manipulation or polarization control can be obtained with quarter wave plate [18]-[24]. The phase difference between outcome two orthogonal transmitted waves is quarter of the wavelength 90^o when impinged wave is linearly polarized at 450 and quarter wave plate has ability to change the impinged wave to circular polarization [25].

Frequency selective surface (FSSs) are developed as special filter and polarization transformer for microwave and millimetre waves. They are considered for many applications such as telecommunication, dichroic reflectors, waveguides and wireless security. [26-28]. FSSs can also be considered as polarizer [29-31] which has overall good performance and ease fabrication. The structure based on 15 x15 arrays of dual split ring resonators to demonstrate the transmission phase [32].

2. Structure of Single Layer Polarizer

First of all we have proposed single strip polarizer that operate at 13.20 GHz is designed and fabricated to produce perfect right hand circular polarization. This single strip acts as a quarter-wave plate that transforms a linearly polarized incident wave into a circularly polarized transmitted wave. A single strip oriented at 45° with λ/4 arm length along the x-y plane in simple unit cell. Whereas, the lengths of the single strip in x-y directions is 7.5 mm and width is 2 mm. Perfect Electric Conductor (PEC) material is used to the strip. The periodicity positions of the unit cell in three axes are X=28, Y=, 28 and Z= 25.25, respectively.

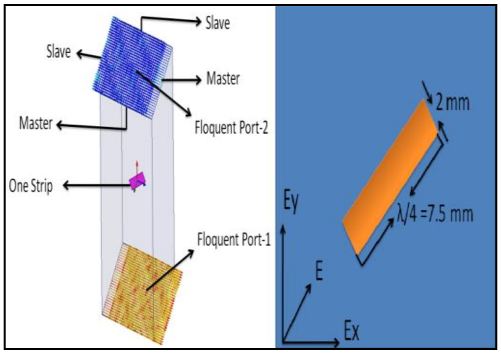

Fig. 1. View of circular polarizer based on single strip.

3. Structure of Circular Polarizer

Circular polarizer using FSS design for 15.25 GHz and 15.28 GHz applications. Using this FSS to obtain CP at resonant frequencies. In this structure, two metallic strips are placed perpendicular at angle +45º and -45º along x-y directions and separated at the distance of 7.2 mm perpendicularly from each other. The FSS polarizer is depicted in Fig.2. The proposed structure is constructed as cross dipole with λ/4 arm length along x-y axis. The length of each strips are selected 7.5 mm and 2mm wide, respectively. The Perfect Electric Conductor (PEC) material is used to strips. The periodicity positions of the unit cell in three axes are X=33, Y=, 33 and Z= 54, respectively.

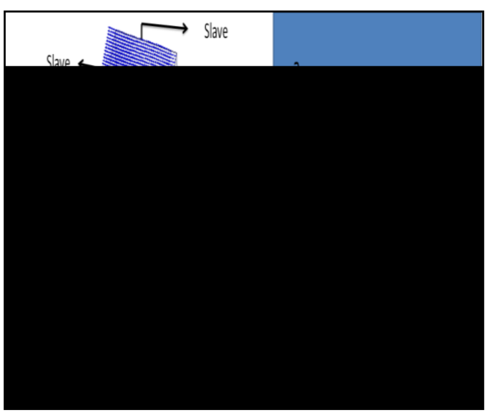

Fig. 2. View of Circular Polarizer based on two metallic strips.

4. Simulation Analysis

For simulation purpose, the HFSS software is used in terms of periodic boundary conditions. The impinged wave through floquet port one converted into circular polarized waves. The incident EM wave slanted at 45º and emerge in to two decomposed orthogonal waves E_x and E_y to realize pure CP as shown in Fig.1. It can be observed that the transmission loss of designed structure -3.2 dB at the 13.2 GHz as depicted in Fig. 4. The axial ratio is 1.1 corresponds to phase difference of 90º at resonant frequency of 13.2 GHz mentioned in Fig.3 & 5. The RHCP wave and LHCP wave are generated at distinct resonant frequencies. The transmission loss of dual Polarizer at the RHC polarization is -1.8 dB and at LHC polarization is -2.6 dB with respect to resonant frequencies 15.25 GHz and 15.28 GHz. Meanwhile, corresponding phase differences between outcome waves E_x and E_y are depicted in Fig. 5 and 8. The simulated phase differences of outcome waves are satisfied at 90º to achieve pure CP at resonant frequencies.

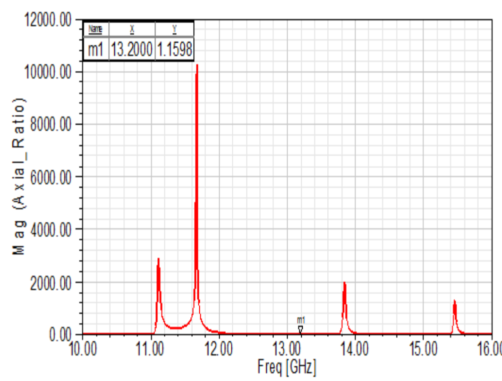

Fig. 3. Axial ratio at 13.20 GHz.

5. Theoretical Results

The HFSS software is used to analyze the obtained phase difference and magnitudes of output orthogonal components through designed low loss transmission circular polarizer. While, phase difference and transmission magnitudes of outcome waves can be directly calculated by formula E_x/E_y and $\Delta\phi = E_x\phi - E_y\phi$.

In Fig.1, the unit cell structure is depicted in Fig.1 which is oriented at 45° in x-y direction. The transmitted of two orthogonal waves is same at 13.20 GHz which converts linear-to-circularly polarized wave. The calculated axial ratio of outcome two waves is 1.1 at 13.20 GHz depicted in Fig. 3. The low loss transmission of the generated waves is noticed due to reflection of polarized constructed by single metallic strip. The generated orthogonal waves are same at 13.20 GHz but transmission loss about -3.2 dB is observed. Obviously, the calculated transmission loss impact on the transmission power through single layer structure. The calculated phase difference of CP is 90° at the 13.20 GHz which corresponds to axial ratio between two outcome waves as mentioned in Fig. 3.

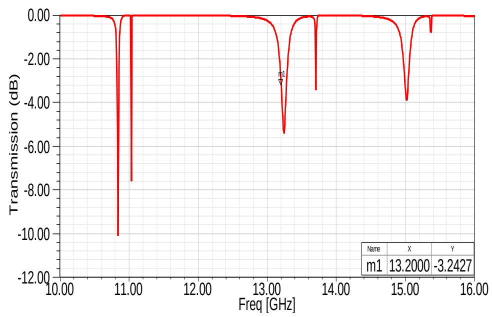

Fig. 4. Transmission magnitudes at 13.20 GHz.

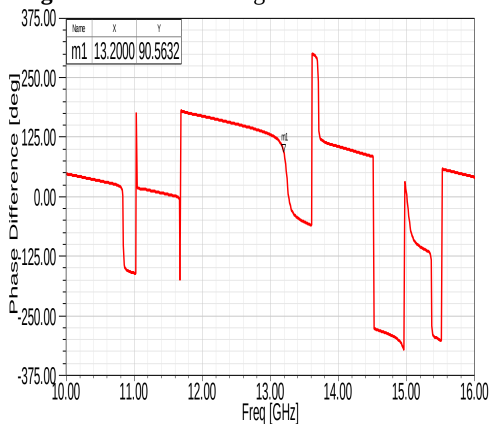

Fig. 5. Phase difference at 13.20 GHz.

The transmission loss of single-layer polarizer oriented at 45^0 in x-y direction is -3.2 dB as shown in Fig. 4. Furthermore, a innovative technique has been proposed to reduce transmission loss of single polarizer based on introducing the dual layer polarizer mounted perpendicularly to each other in the x-y direction as shown in Fig. 2.

The magnitudes of output orthogonal components are similar at the frequency of 15.25 GHz and 15.28 GHz to obtain the RHCP and LHCP. Nevertheless, it is necessary to obtain the circular polarization the phase difference of two orthogonal components E_x and E_y of E field must be satisfied at 90^0 .The transmission axial ratio between two orthogonal components is 1.4 and 1.2 at 15.25 GHz and 15.28 GHz as shown in Fig. 6. Whereas, the phase difference between two orthogonal components E_x and E_y is calculated by the phase difference formula of circular polarization.

The transmission loss after reflection from the Polarizer surface as shown in Fig.7 indicates the transmission magnitude of E components E_x and E_y in dB are -1.8 at 15.25 GHz and -2.60 at 15.28 GHz as shown in Fig. 7. It means that the magnitude of both orthogonals E_x and E_y components are same. The transmission loss is observed -1.8 and -2.6 dB that effect the transmission of waves through polarizer. It is observed that the transmission loss of dual layer polarizer has been reduced against single polarizer as shown in Fig. 7. The circular polarization can be calculated by the following expression.

$$\Delta\emptyset = \emptyset\mathbf{y} - \emptyset\mathbf{x} = \begin{cases} +\left(\frac{\mathbf{1}}{\mathbf{2}} + \mathbf{2n}\right)\boldsymbol{\pi}, \mathbf{n} = \mathbf{0}, \mathbf{1}, \mathbf{2}, \dots \dots \dots \dots \\ +(\left(\frac{\mathbf{1}}{\mathbf{2}} + \mathbf{2n}\right)\boldsymbol{\pi}, \mathbf{n} = \mathbf{0}, \mathbf{1}, \mathbf{2}, \dots \dots \dots \dots \end{cases} \quad (\mathbf{1})$$

It is observed circular polarization achieved when axial ratio value of two orthogonal components is satisfied 1.2 at certain mentioned frequencies and correspond to 89.9^0 phase difference of two components.

Therefore, we have achieved at about 99% RCP and LCP at the frequencies of 15.25 GHz and 15.28 GHz as shown in Fig.6 and 7. The phase difference is calculated by deducing the value form Fig. 8 and verified by above equation 1.

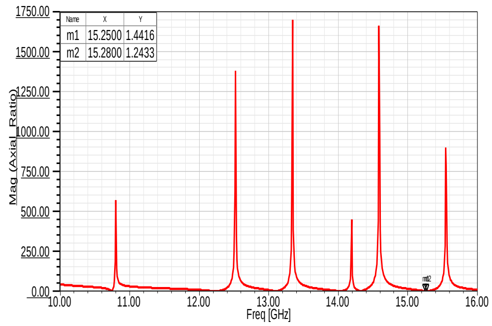

Fig. 6. Axial ratio is at 15.25 GHz and 15.28 GHz.

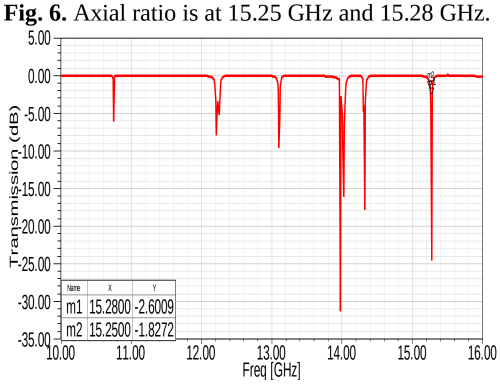

Fig. 7. Transmission magnitude at 15.25 GHz and 15.28 GHz.

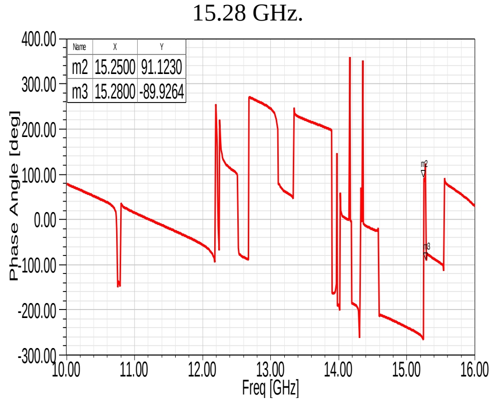

Fig. 8. Phase difference at 15.25 GHz and 15.28 GHz.

6. Conclusion

In conclusion, we proposed the low loss transmission circular polarizer using two metallic strips to investigate the transmission characteristics with pure circular polarization at 15.25 GHz and 15.28 GHz. The designed structure is based on FSS which generates the THCP wave and LHCP wave at resonance frequencies. The constructed model is simple and could be designed and fabricated easily by using HFSS software with high precision. The reflection and transmission characteristics are good features of the designed structure. In addition, the design techniques can be employed to construct the polarizers using double layer polarizers based on metallic strips or split ring resonators for millimetre, micrometre and terahertz frequencies. In future, this research can be carried out to compose polarizers using FSSs to extend the bandwidth and reduce the transmission loss.

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