Transmission Characteristics of Quarter Wave Plate Circular Polarizer Based on Frequency Selective Surface for High Frequency Applications

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Abstract-**The broadband performance of quarter wave plate circular polarizer based on FSS is presented for high frequencies applications. Currently, the transmission loss and broadband of circular polarizer at desired frequencies is important issue for high frequencies application. Here, we are introducing some novel ideas to generate good circular polarization and significant techniques to improve broadband of circular polarization and low loss transmission by using single layer polarizer. The Simulation results show that the transmission loss -2.4 dB of single layer polarizer has been achieved at 70.70 GHz and pass band is extended from 69.29–71.78 GHz.**

Keywords-frequency selective surface (FSS); quarter wave plate; dual layer polarizer; Fabry-Perot Interferometer; circular polarization

I. INTRODUCTION

The significance of detection and manipulation of the polarization state of electromagnetic waves have great interest in variety field of microwave and optical communication, wireless communication, radar and tracking applications [1-3]. Circular polarization has 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).

Circular polarizers based on meander line in microwave technology is introduced by Young [4] and presented by Munk [5]. Currently, Euler [6] has introduced the various types of dual layer circular polarizers in which the space between the surfaces of layers is adjusted by the Fabry Perot interferometer approach [7]. Quarter wave plate is another approach to transfer linearly polarized waves to circularly polarized waves. A quarter-wave plate converts electromagnetic waves from linearly to circularly polarised states or vice versa [8-14]. For a quarter wave plate, the transmitted phase difference of two orthogonal components of electric field is a quarter of a wavelength (90^0). When an incident field is linearly polarized at 45^0 and the quarter-wave plate converts the transmitted field to circular polarization, which has applications in satellite communication and rain clutter suppression [15].

For several years, Frequency Selective Surface has gained more attention in modern communication. Frequency selective surfaces (FSSs) are also used as polarizers, polarization transformer, filters, band-pass hybrid radomes for radar cross section (RCS) controlling [16-21] 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 [22-23].

The pass band through polarizer is important issue in the field of wireless communication system; For instance, previous several published contributions [24], it has been observed that the poor broadband of circular polarizer was achieved at 75 GHz. Nevertheless, Fabry Perot Interferometer approach is introduced to fabricate FSS polarizer to improve the pass band [25].Another recent published contribution in which the transmission loss of the polarizer has been reduced 0.3 dB at 70 GHz but band pass has not been improved with respect to axial ratio [26]. Currently, the FSSs 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 novel approach has been introduced to design a single layer polarizer for high frequencies application that is quite different from previous several published contribution. We have improved the band pass which is extended form 69.29–71.78 GHz. The FSSs polarizer has several advantages over at present available circular polarizes, such as, broadband efficiency, perfect circular polarization, simple structure, high polarization efficiency, and easily fabrication.

II. SINGLE LAYER POLARIZER DESIGN

In this paper circular polarizer based on single layer FSS is designed high frequency applications. In unit cell, single dipole structure is designed at the angle -45^0 along the *x, y* direction, respectively. The length of single strip is *l* and wide *w*. whereas, perfect electric conductor (PEC) is assigned to the strip. The periods in *x*- and *y*- direction are P_x and P_y, respectively.
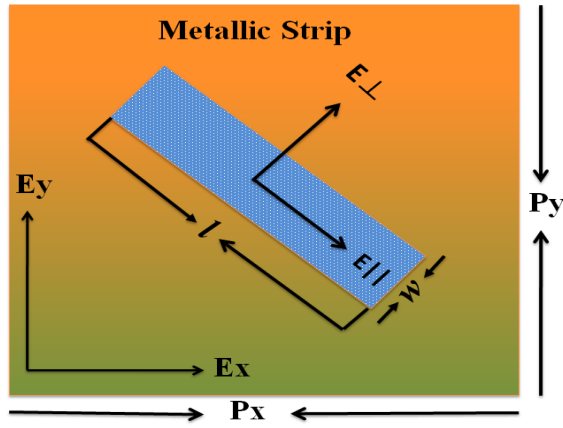
FIGURE I.   THE DIMENSIONS OF SINGLE LAYER STRIP WITH ELECTRICAL FIELD ORIENTATION.

III. SIMULATION SET UP

The unit cell of single layer FSS polarizer is depicted in Fig. 2. The periodic boundaries are selected in x and y direction. Whereas, x polarized wave is used as the excitation source through floquent port one of this model to achieve circular polarization. The frequency domain solver HFSS-15.0 is used to simulate the single layer FSS with respect to periodic boundary conditions as shown in Fig.2. The structure parameters are selected as l = 3.6 mm, w = 2.14 mm and Px = 8.4 mm and Py = 8.4 mm.

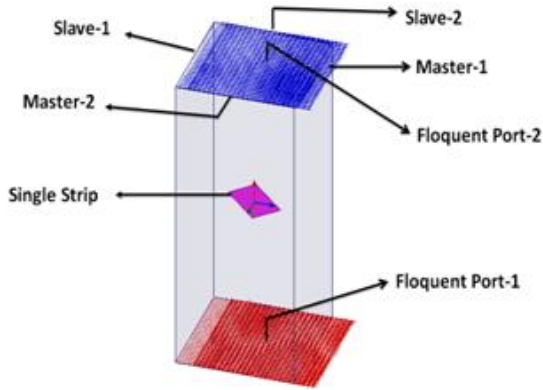FIGURE II. SIMULATION MODEL OF SINGLE LAYER POLARIZER.

A. Simulation Results & Discussion

When electromagnetic waves incident on the first layer the output E field from strip can be decomposed in to two orthogonal and linear electric field vector components (E|| and E⊥) with equal magnitude. After EM waves passing through polarizer, the phase difference 90^0 between two transmitted orthogonal components (ET|| and ET⊥) can be produced with perfect circular polarization.

The probes of HFSS are used to calculate the output required parameters. After completing the simulation, the export based processing option is used to calculate the phase difference and the axial ratio of E components Ex and Ey while the transmission magnitudes and Phase shift of E field

can directly be determined by the expression of Ex/Ey and Δϕ = Exϕ - Eyϕ.

The transmission loss is observed of the single layer polarizer where the radiated orthogonal components are same at the 70.70 GHz but the transmission loss about -2.4 dB is noticed as shown in Fig.3.
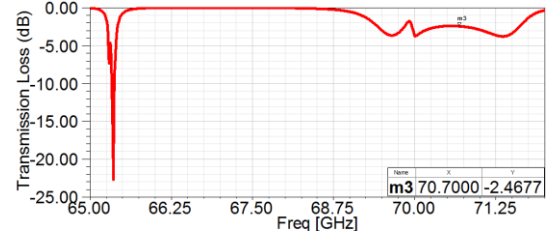

FIGURE III. TRANSMISSION MAGNITUDE OF EX AND EY OF E-FIELD VERSUS FREQUENCY.

The phase difference between two orthogonal components is required 90^0 to satisfy the perfect circular polarization. Here, the phase shift of two orthogonal components Ex and Ey is $90^0.20$ at the 70.70 GHz to obtain the transmitted wave are perfect circular polarization that is equal to the transmission axial ratio between two orthogonal components as shown in Fig.4
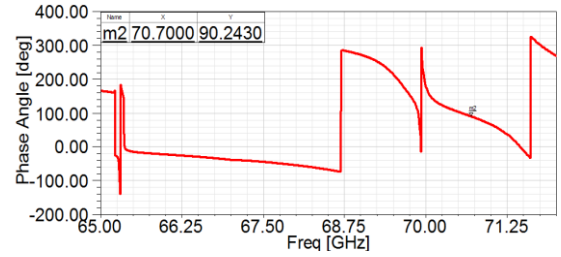

FIGURE IV. PHASE DIFFERENCE OF E-FIELD VERSUS FREQUENCY.

The magnitude of orthogonal components Ex and Ey remain same at the resonance frequency after transmission through FSS polarizer. The simulated axial ratio of circular polarizer is 1.2 that is equal to the phase difference 90.20 at 70.70 and pass band extends from 69.29–71.78 GHz as shown in Fig: 5.
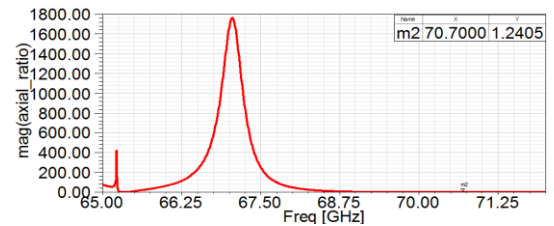

FIGURE V. SIMULATED AXIAL RATIO VERSUS FREQUENCY.

The most significant feature of this proposed designed model by using optimization techniques is to achieve the best results of FSS circular Polarizer. It is observed that the magnitudes of E component Ex and Ey are same at the frequency of 70.70 GHz to obtain the perfect circular polarization. The pass band extends from 69.29-71.78 GHz. The phase difference of Ex and Ey is 900 and the magnitude

values of Ex and Ey are same at 70.70 GHz frequency, so approximately 100% circular polarization is achieved. Meanwhile, calculated values of circular polarization is deduced by the following equation (1) and verified by HFSS Software.

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

IV. CONCLUSION

The transmission characteristics of single layer polarizer has been investigated and achieved good circular polarization at 70.70 GHz. The best simulation results with good circular polarization on the pass band of 69.29-71.78 GHz frequency have been obtained with low loss transmission -2.4 dB. The designed model is very simple and can be easily fabricated. Therefore, the same technique can be applied to fabricate single layer polarizers to enhance the bandwidth and minimize the transmission loss for millimetre, micrometre and terahertz frequencies according to desired applications. Nevertheless, it could possible by changing some parameters, such as by extending the dual, triple and multilayer, increasing or decreasing the length of each strips, adjusting the distance between layers and thickness of the layers.

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