Dual band Chiral Metasurface for Linear to Linear Asymmetric Transmission Applications

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***Abstract*— In this paper, a dual band chiral metasurface is presented to realize high efficiency asymmetric transmission for linearly polarized electromagnetic waves in microwave regime. The y-incident wave is converted into its orthogonal cross component within the frequency band of 17.5-18.9 GHz while x-polarized wave is converted into its cross component within the frequency band 9.53-10.13 GHz. The parameter of asymmetric transmission goes up to 0.8 at resonance frequencies. The maximum value of polarization conversion ratio (PCR) is more than 85% in the frequency bands of interest.**

Keywords—Chiral metamaterials; metasurfaces; asymmetric transmission; linear polarization conversion, PCR

I. Introduction

Metasurfaces have recently gained a lot of attention due to their intriguing properties of controlling and manipulating the electromagnetic (EM) waves to achieve the desired response which cannot be achieved through naturally occurring materials [1-3]. Chiral metamaterials lack mirror symmetry in the structure and can be used for manipulation of EM waves Strong optical activity, circular dichroism, polarization conversion and asymmetric transmission (AT) are some of the phenomenon exhibited through chiral metamaterials. Fedotov et al. first illustrated AT by proposing a design of a planar chiral metasurface [4] and research interest in this area has gained importance since then. Asymmetric Transmission is a diode like operation, where the wave propagates only in one direction. In the past, split ring resonators in different configurations have been proposed [5-6]. However, the operating bandwidth of asymmetric transmission of these structures is very narrow.

In this paper, a single layer chiral metasurface has been proposed to perform asymmetric transmission and polarization conversion of y-polarized wave into x-polarized wave in one band of operation from 17.5-18.9 GHz. Similarly, x-polarized wave is converted into y-polarized wave in the frequency band of 9.53-10.13GHz. The structure achieved asymmetric transmission up to 0.8 and 0.72 in the two bands respectively. The achieved PCR is more than 85% within the bands under consideration.

II. Unit Cell Configuration

The unit cell of the proposed metasurface is shown in Fig. 1 (a)-(b). Chiral geometry is obtained by rotating the bottom layer by 90° with respect to the top layer. The Rogers RT5870 of thickness 1.57 is used as a dielectric substrate with dielectric constant 2.33 and loss tangent 0.0012. The top and bottom layers are made up of copper having thickness of 35μm with conductivity 5.8×10^7 S/m. The dimensions of the structure (in millimeter) are a=b=7, r1=3.2, r2=2.4, d=0.2, e=0.9, g=1.

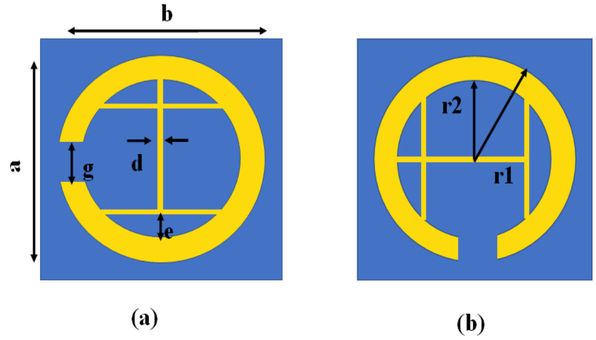

Fig. 1: (a) top view (b) bottom view of the proposed unit cell

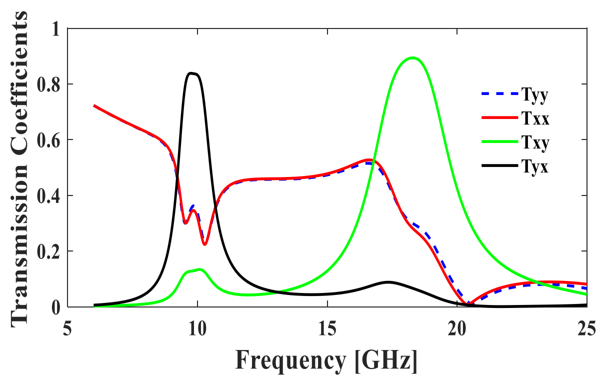

Fig. 2: Simulated transmission Coefficients of co- and cross-components for the normal incident

III. Results and Discussions

Linear polarization conversion is obtained when the incident x-polarized EM-wave is converted into its orthogonal component in transmission mode and vice versa. Due to strong EM coupling in the structure, the magnitude of the cross conversion is increased. The structure satisfies the condition of asymmetric transmission i.e. $T_{xx} = T_{yy}$ and $T_{yx} \neq T_{xy}$ as shown in Fig. 2.

A. Polarization Conversion Ratio (PCR)

A parameter to show a good measure of cross conversion is known as polarization extinction ratio (PCR). Equation 1 and 2 are used to define the PCR for y-incident wave to x-polarized wave and x-incident wave to y-polarized wave respectively [7].

$$\text{PCRy} = \frac{|Txy|^2}{|Txy|^2+|Tyy|^2} \quad (1)$$

$$\text{PCRx} = \frac{|Tyx|^2}{|Tyx|^2+|Txx|^2} \quad (2)$$

Txx and Tyy are the co-components while Txy and Tyx represent the cross transmission coefficients and possess the values of 0.9 and 0.8 respectively within the mentioned frequency bands as depicted in Fig 3. The magnitude of PCR more than 85% has been achieved within the frequency band of 17.5-18.9 GHz and more than 90% in 9.53-10.13 GHz. The Fig. 3 depicts the PCR for both polarization conversions.

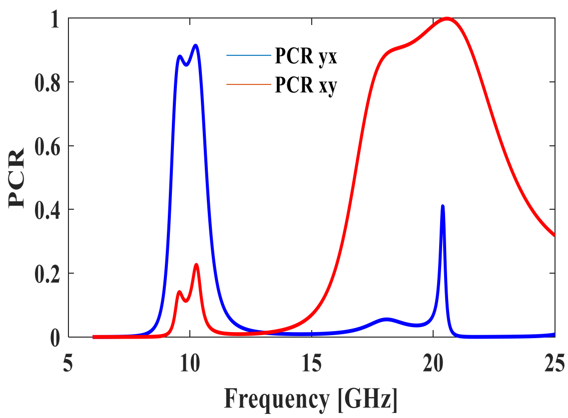

Fig. 3: PCR for y-incident and x-incident waves

B. *Asymmetric Transmission*

As shown in Fig. 4, the structure fulfills the conditions of asymmetric transmission, the co-components are the same and there is a distinct difference between the cross components. Asymmetric transmission parameters up to 0.8 and 0.72 are obtained as shown in Fig. 4.

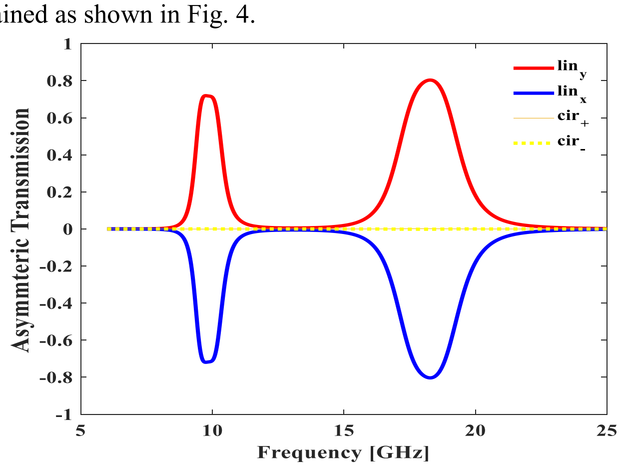

Fig. 4: Asymmetric transmission parameter for linear wave and circular wave

AT for linearly polarized wave is defined by equations 3 and 4 as [7],

$$\Delta lin^y = |T^f xy|^2 - |T^f yx|^2 = |T^f xy|^2 - |T^b xy|^2 \quad (3)$$
$$\Delta lin^x = |T^f yx|^2 - |T^f xy|^2 = |T^f yx|^2 - |T^b yx|^2 \quad (4)$$

Figure 5 depicts the behavior of the structure at oblique incidences. The simulated results show that the design is angularly stable up to 30°.

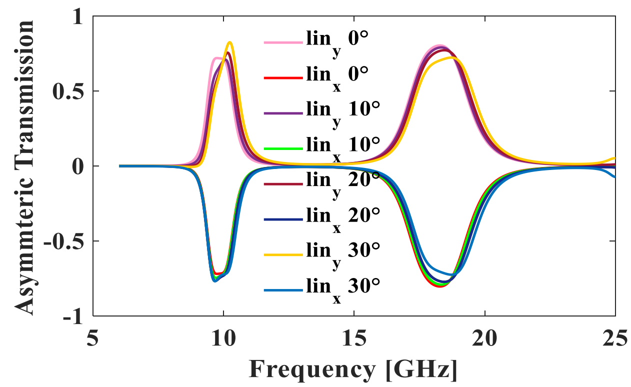

Fig. 5: Asymmetric transmission parameter at oblique incidence.

IV. CONCLUSION

In this research, a dual band asymmetric chiral metasurface is demonstrated that converts linearly polarized incident wave into cross polarized wave in transmission mode. The metasurface design has achieved the magnitude of asymmetric transmission equal to 0.8 and 0.72 within the bands of 17.5-18.9 GHz and 9.53-10.13 GHz respectively. The y-incident wave is converted into x-polarized wave with conversion efficiency more than 90% and x-polarized wave is converted into y-polarized wave with conversion efficiency more than 85%.

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