[1]

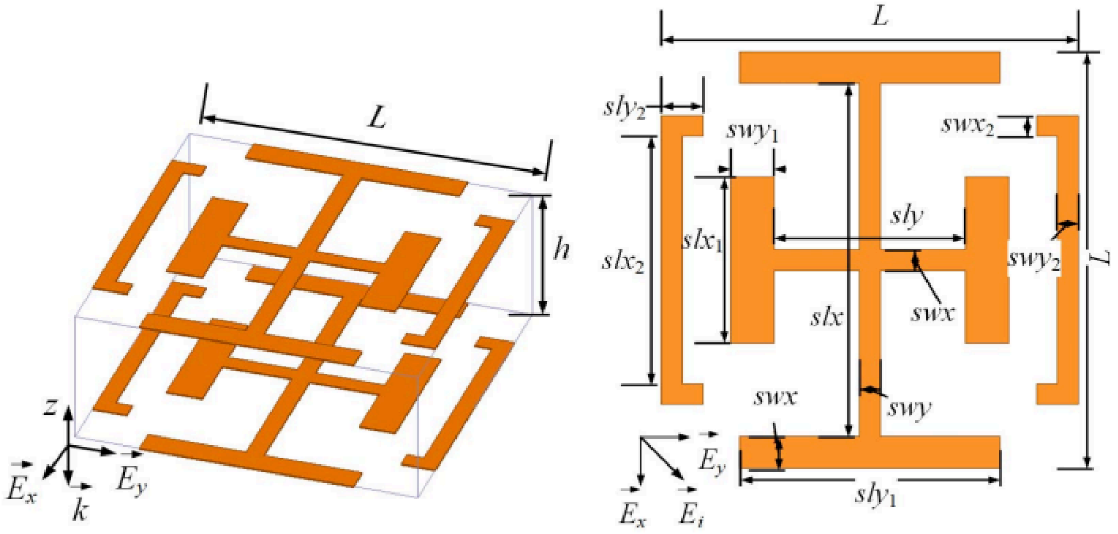
Linear-to-Circular Polarization Conversion Using Metasurface

This study revolves around the transformation of linear polarization (LP) into circular polarization (CP) with the aid of an antenna and a metasurface. There are two kinds of antennas that have been analyzed; they include patch and slot antennas. The metasurface array consists of rectangular loops that are diagonally organized into a 4x4 cell array. The LP signal produced by the source antenna is transformed to CP through use of the metasurface. Both antennas operated at 2.45 GHz frequency. The two antennas point out their simulation design initially before being built so as to check how they perform in practice. Results obtained showed that metasurface antennas outperform patch antennas in terms of gain, return-loss bandwidths as well as axial ratio bandwidths.

A metasurface consisting of a square ring with a diagonal strip is used as a superstrate to a linearly polarized antenna to make it circular polarized in [1]. The MS consisted of 4X4 elements of the unit cell to match the size of the antenna geometry. To further evaluate and analyze the performance of the designed/ proposed geometry, patch and slot antenna's operating at 2.45GHz were employed/used. It is observed that there is a significant enhancement in their gains and bandwidths. From the results of axial ratios, the antennas which were designed for linear polarizations were exhibiting circular polarization(write the values of gain enhancement, bandwidth and axial ratio). Therefore it is understood that, through the proposed squared ring diagonal strip structure, linearly polarised the antenna is converted to circular polarized.

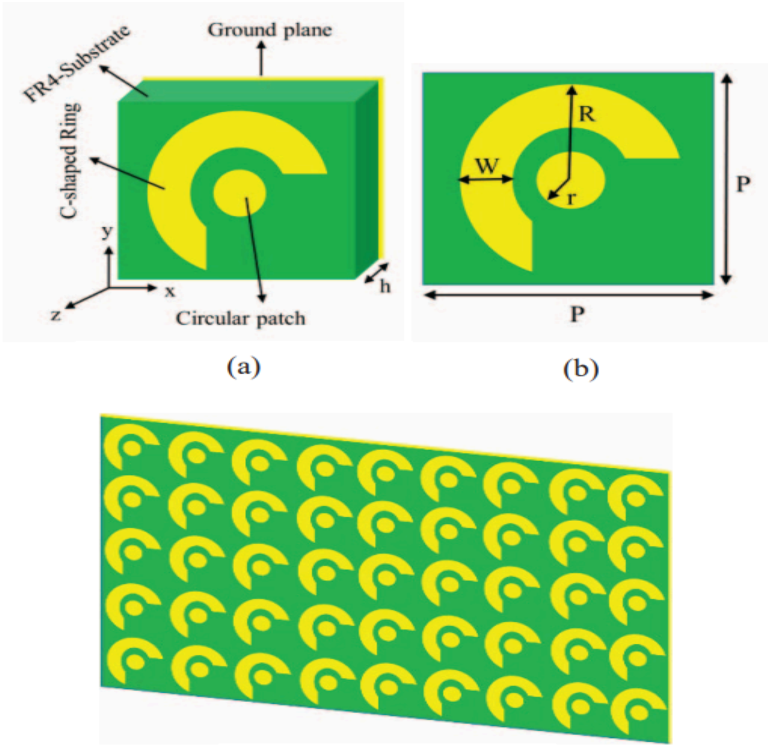
[2]This work introduces a dual band linear to circular polarization converter using a single layer dielectric substrate.The elements in the converter consist of two identical metallic layers which is the combination of Jerusalem cross(jc) and I type dipole. The introduced converter designed using equivalent circuit model(ECM).Converter generates a K-band(18-27GHz) for left-handed circularly polarized(LHCP) and Ka band(26.5-40GHz) for right handed circularly polarized.When excited by a linearly polarized(LP) wave tilted 45° relative to the x and y directions of the converter.This dual band design supports K/Ka band satellite communications with high conversion efficiency and a low polarization extinction ratio(PER).After full-wave optimization,the converter was fabricated and tested,with measurements closely aligning with simulations.There is a tradeoff between between angular

stability and bandwidth,the measured axial ratio(AR) remains stable in K-band and shows only slight fluctuations in the Ka-band at an incident angle of 20°.



(a) (b)

[3]The paper presents the metasurface designed to change the polarization of light from linear to circular polarization(LTC). The metasurface is made up of repeated units called unit cells[c].It has two main parts which are outer c-shaped ring and meta circular path….c-shaped ring is the metallic ring with a shape like letter "c" where meta-circular path that is round metallic piece placed in the center of the c-shaped ring. In this polarization conversion when a linearly polarized wave hits the metasurface and its works effectively across the frequency range of (15.26Ghz-18.70Ghz),in the case of 3db it tells how well the polarization conversion is achieved in that given frequency range, moreover LTC polarization conversion efficiency means how effectively the meta surface changes the polarization which is above [90%] for the frequency between (16 Ghz to 18Ghz). And it would be useful in designing microwave devices that need to control the polarization.



(a) (b) (c)

MULTIBAND REFLECTIVE POLARIZATION CONVERTER USING METASURFACE

Metasurfaces are composed of artificial engineered periodic resonant structures which have the ability to alter the amplitude, frequency, phase and polarization of the incident electromagnetic wave. Several challenges occur to establish communication links, few of them would be atmospheric mismatches, reflection effects and polarization mismatches etc. Polarization mismatching occurs due to differences in polarizations of transmitting and receiving antennas. To overcome this circular polarized antennas can be used. However, designing circular polarized antennas requires complex feeding techniques which may not be feasible. Metasurface possesses the ability to control the polarization of an EM wave, metasurface can be integrated along with the antenna, to alter polarization of the antenna. Therefore by using metasurface as a superstrate it facilitates the conversion of linear polarization to circular polarization which overcomes the challenges of polarization mismatching faced in communication links. In this work we are designing a metasurface which can convert the polarization of the linearly incident EM wave into circular polarization during the reflection phase. In our work we design a polarization converter which can operate between 4-8GHz and also design an antenna which can operate in 5G and analyze its polarization conversion ability without altering the feeding techniques. Moreover, we also study the impact of the metasurface in terms of other characteristics of an antenna.

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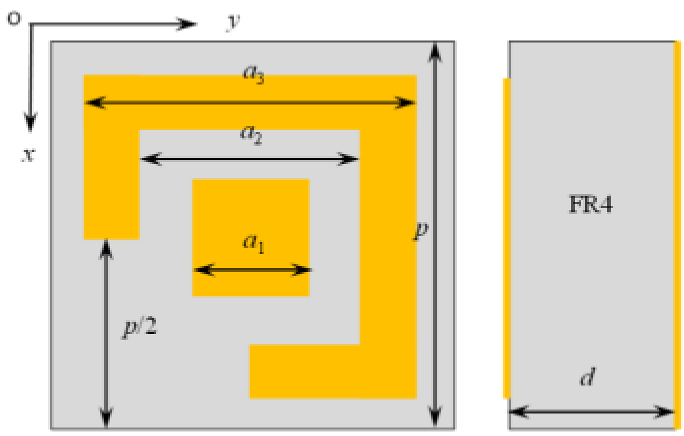
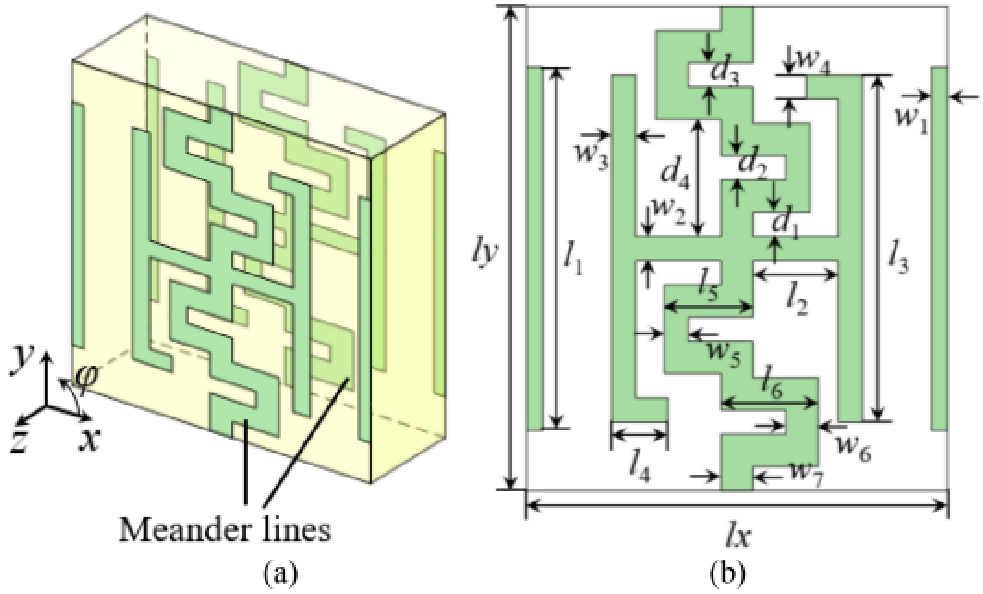
[4]A dual band reflective linear to circular band polarization which do the dual reflection based on frequency selective surface is designed.The unit cell consists of a square patch and a open ring whereas open ring creates two resonances and the square patch used to increase the axial ratio the designed band works on two frequency bands i.e 29.0-41.5GHz(former band) and 52.5-61.5GHz(later band) when the linearly polarized wave come reaches the band in x-direction then the band converts it to right-handed circularly polarized wave and the waves in y-direction will be converted into left-handed circularly polarized wave.this works viceversa with the later band. The design demonstrates 45 degrees angular stability for 3dB. AR over two operational bands.This design is made by using only single substrate,which makes fabrication easy.TThe insertion loss is very less as 0.5 dB and the unit cell is less than 0.2 wavelength at lower frequency band.

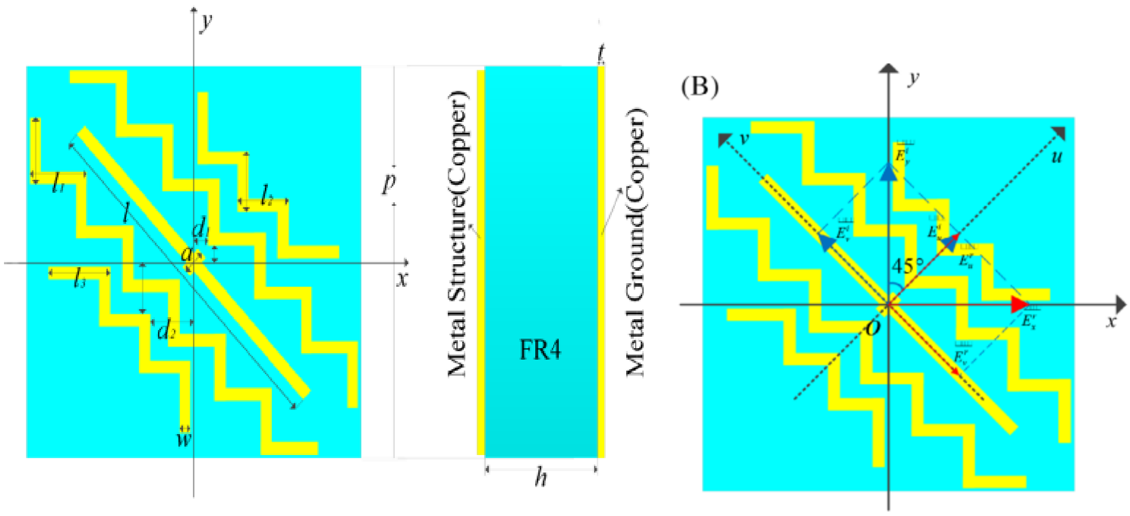


[5] Dual-band linear to circular polarization converter(LDCP) is based on single layered substrate for both K-/Ka band satellite communication whereas K-band works for 17.7-20.2GHz and Ka band works for 27.5-31GHz in orthogonal circular polarization.

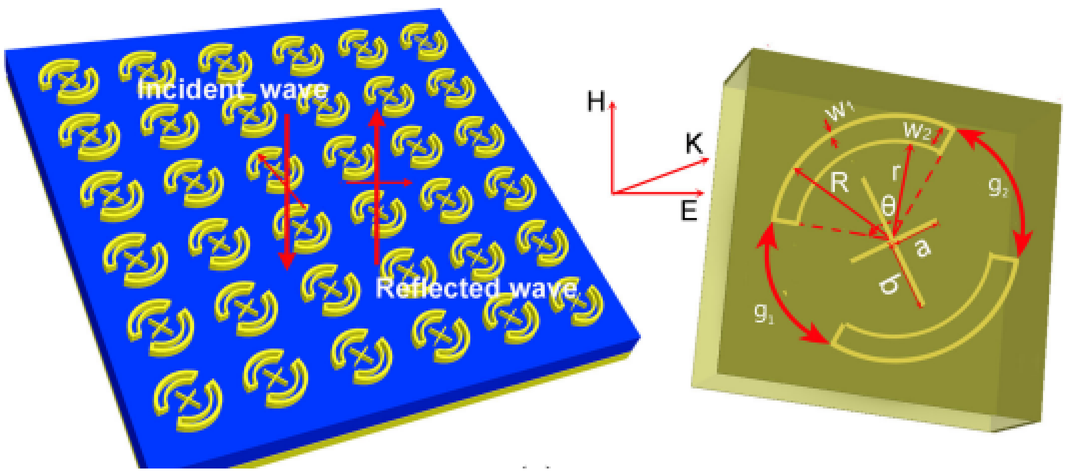
This design contains 31×27 elements with the size of 100×100 mm.The unit cell is composed of non resonant meander lines and strips with identical shape on both sides of the substrate.It allows the high efficiency transformation from linear polarized wave to orthogonal circular polarized waves at operating bands.It gives the high angle stability of ±45°. The converter shows the 3dB AR bandwidths of 21.8% and 12.6% in the lower and upper bands.



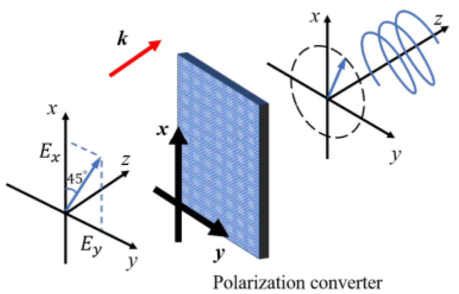
[6]Single-band linear-to-linear and dual-band linear-to-circular polarization converter is designed using the single layer reflective metasurface. A single unit cell of metasurface is structured with an inner cross and a pair of outer serpentine lines on substrate with a metallic layer on the other side to facilitate reflection. The impedance matching is easier with these serpentine structures. This metasurface construction gives 95% of polarization reflection ratio (PCR) for middle frequency ranges of 9.33-11.77 GHz, a linearly polarized reflected wave is given. When a y-polarized wave is incident on this metasurface it is converted to circular polarized wave in nonadjacent bandwidth ranges of 5.95 to 8.80 GHz and 12.8 to 15.58 GHz.

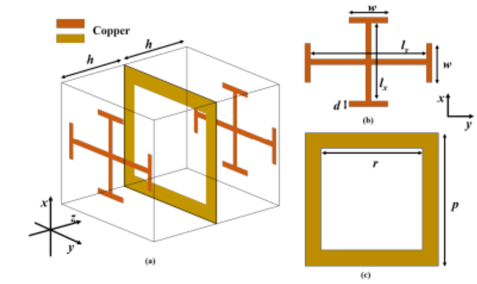


[7]A broadband high-efficient linearly polarized converter is created using anisotropic metasurface. The metasurface consists of three layered sandwiched structure including an electric resonator layer at the top, followed by an dielectric of F4B(εr = 2.65 − 0.001 j), and full metallic bottom layer.The electric resonator is designed with symmetrical double C-shaped half rings connected with an inner cross structure, which converts nearly- perfect linearly polarized waves to their orthogonal components. The electrical conductivity of the copper plate is 5.8 × 107 S/m and thickness of 35 μm. This is a linear-to-linear converter that is operated between the ranges of frequency of 9.38-13.36 GHz and 14.8-20.36 GHz. This high efficient dual broadband characteristic is obtained by an oblique incidence range of 0-45°.

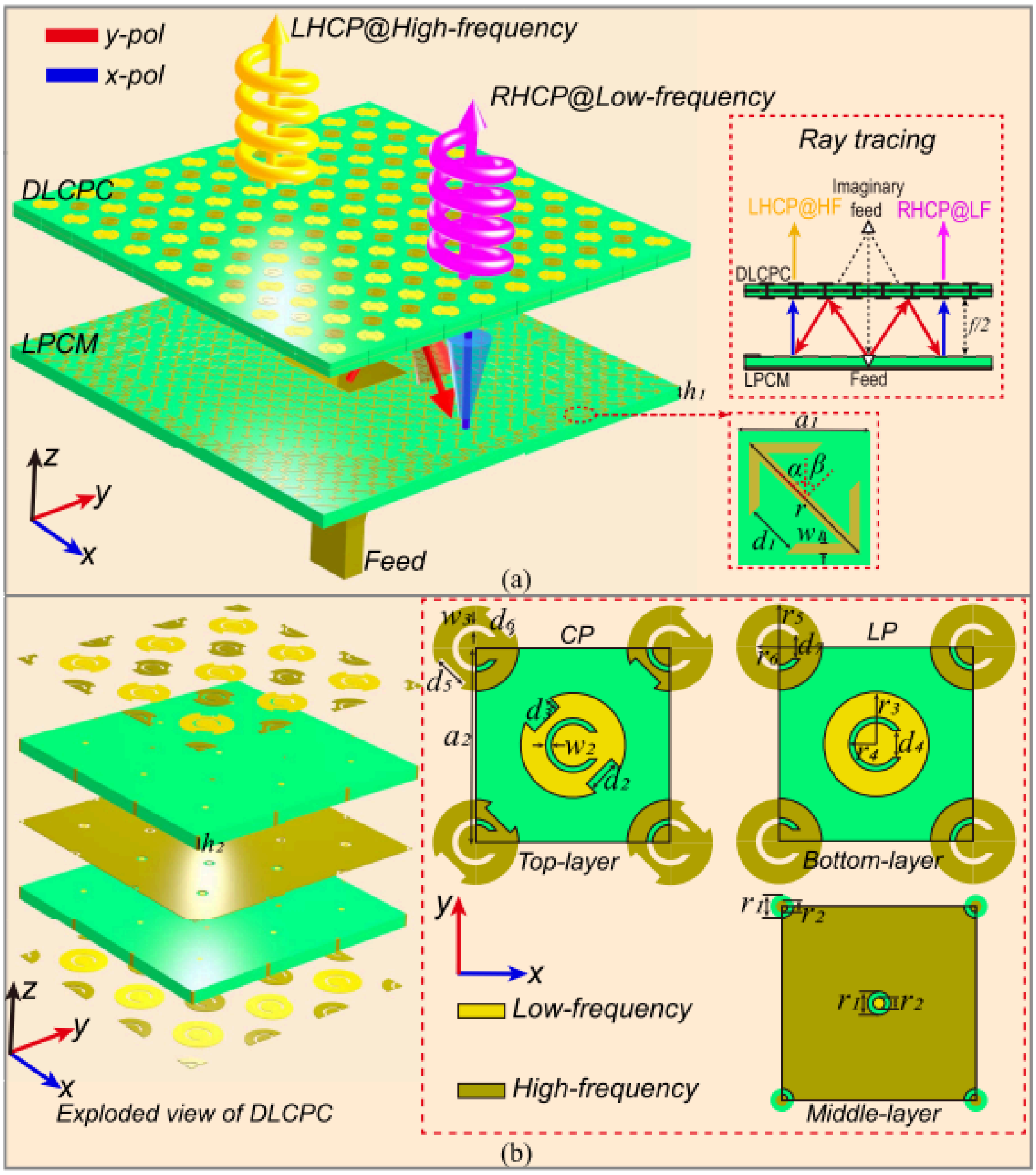


[8]In the study of linear-to-circular polarization converters, the research focuses on a stacked metasurface design that utilizes an aperture coupling layer.. Meta surfaces can convert linear polarized waves into circular polarized waves.. And that consist of two layers of periodic subway length that are Jerusalem cross elements that are used for their unique electromagnetic properties, and which are periodic that are arranged in a repeating pattern. So the combination of Jerusalem cross elements and square rings results in a high performance polarization converter. The anisotropic characteristics of these elements create a 90 degree phase difference between two orthogonal linear polarizations during transmission. for improving the axial ratio, the interlayer aperture coupling ensures a flat and very near to unity magnetic response. so that meta surface prototype was fabricated and simulated for the operation in KU band(12GHz-18GHz). So the results from both simulations and measurements demonstrate a favorable AR within the operating frequency range. This linear to circular polarization can also be suitable in quasi optical applications.





[9]A polarization twisting metasurface antenna is designed to create dual band dual circular polarization radiation by combining a dual linear to circular polarization converter with a frequency selective surface.The linearly polarized waves converts into right hand circular polarization at lower frequency and the waves turn into left hand circular polarization at higher frequencies waves. The common bandwidths of 1.5dB gains and 3dB axial ratios are 12.25-12.95and 14.00-14.55 GHz respectively.



[10]The paper introduced an ultrasound reflective meta surface based multi polarization converter with a periodicity of 0.177λ₀ (λ₀ being the free-space wavelength) For X,Ku,K and Ka band applications. The metasurface unit cell features a diagonally oriented slotted semicircular metallic ring resonator. enables triple band linear to linear polarization. conversion across 10.94-15 GHz, 17.80-18.48 GHz, and 27.08-30.09 GHz . With a polarization convergent ratio of 95%. It also achieves Pentagon leaned to circular polarization conversion of 10.05 GHz, 15.7 GHz, 17.25 GHz, 19.55 GHz, and 25.95 GHz.This design is applicable for X and Ku-band downlink (10.7-12.5 GHz), K-band downlink (19.5-21.5 GHz), and K and Ka-band uplink (25.5-27.5 GHz and 29.5-31 GHz) satellite communications, and

can be integrated with MIMO antennas for reduced radar cross-section (RCS) and mutual coupling.

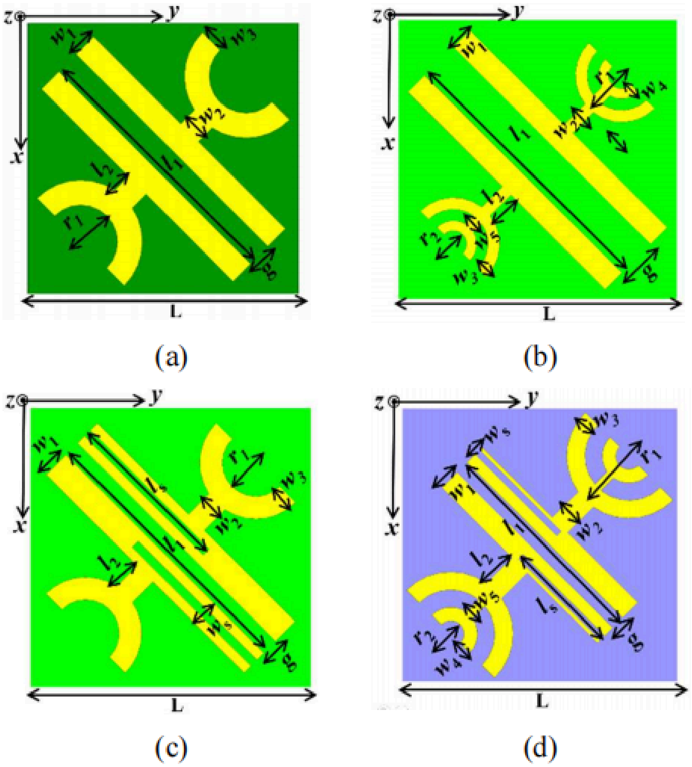


Fig. 1. PC unit cells of (a) single ring broadband (b) dual ring dual band (c) slotted single ring dual band (d) slotted dual ring triple band

[11]This paper talks about converting a linear wave into circular polarization which works on a metasurface.This polarization takes place for the wave in X-band.To get the broad band-width each unit cell is composed of 3 metal layers,both upper and lower metal layers are connected with a metal column,Thus it can provide anisotropy to obtain two orthogonal electric field vectors with 90 degree phase shift but same amplitude.The middle layer is hexagonal metal ring to increase the bandwidth further.The simulated results band-width with 8.92-12.22GHz.When the incident ray angle is about -30° to +30° the designed metasurface has the advantages of broadband width and stability of the incident angles.

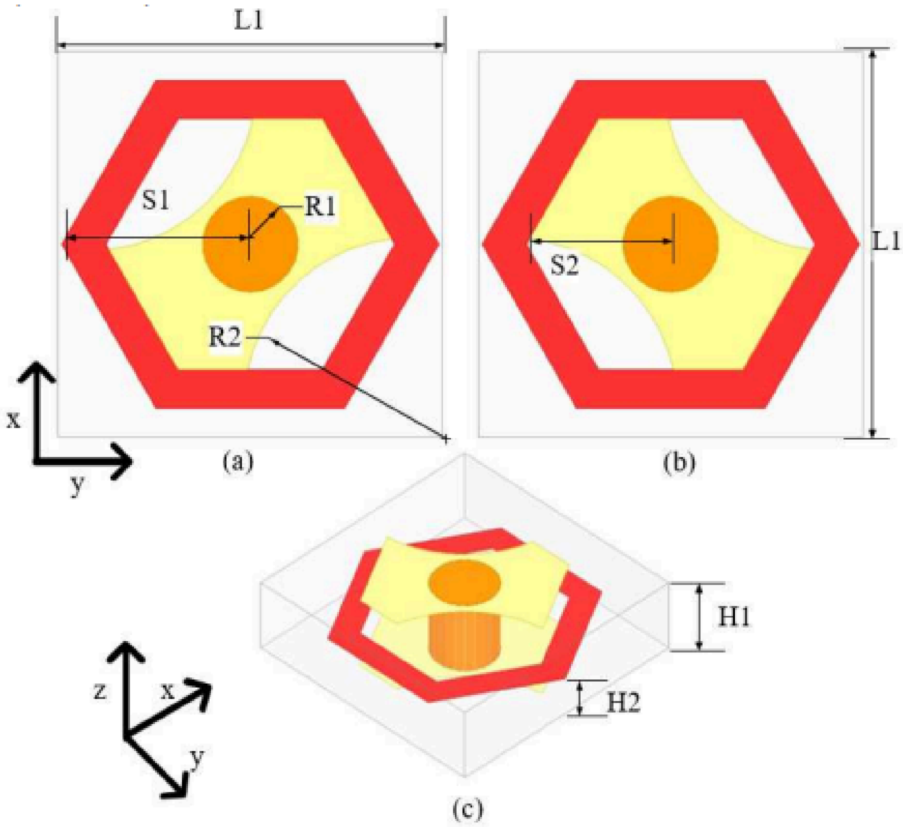
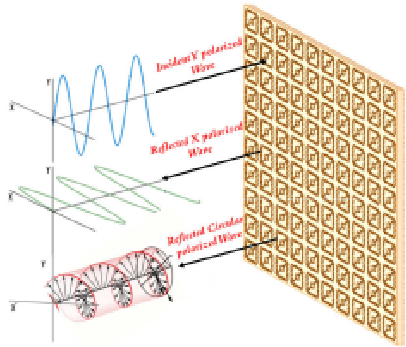
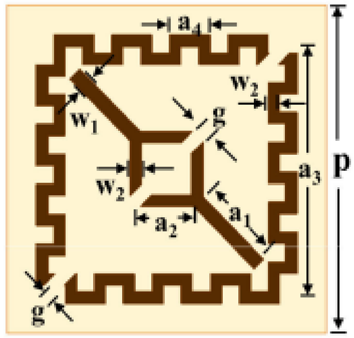


Fig. 1. The element of the metasurface. (a) top layer. (b) bottom layer. (c) 3-D view.

[12]In this work the metasurface unit cell consists of a diagonal split strip and meandering square ring. This simple metasurface operates in multiband and converts linear incident EM to linear in four frequency bands - 4.3GHz, 7.2GHz,12.3GHz and 15.15GHz. And also converts linear to circular or circular to linear Polarization at 4GHz, 4.75-5.95GHz, 8.35-8.8GHz and 1.35-14.6GHz frequency bands. This multi band function is due to the multiple resonances occurring in the structure based on the design of the metasurface. This polarization converter acts as a meta reflector that maintains the circularly polarized wave upon reflection. The metasurface can achieve converting linear waves to both Left Hand Circular Polarized (LHCP) and Right Hand Circular Polarized (RHCP) waves simultaneously with just one metasurface. Since the LP-LP can be carried out in four frequency bands and LP-LHCP and LP-RHCP is carried out in another four bands, its called 8-band Multi-functional reflective polarization converter.



(a)



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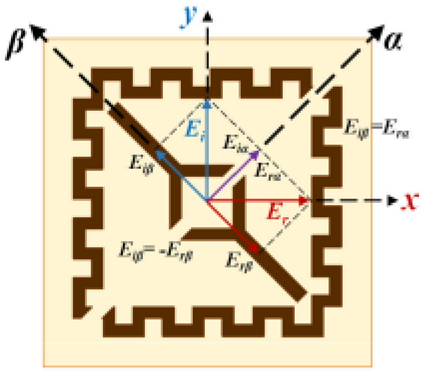
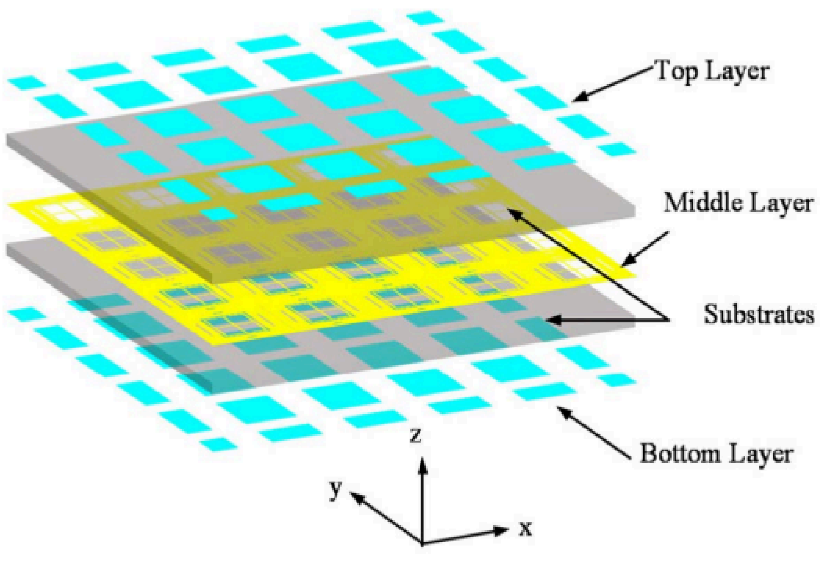
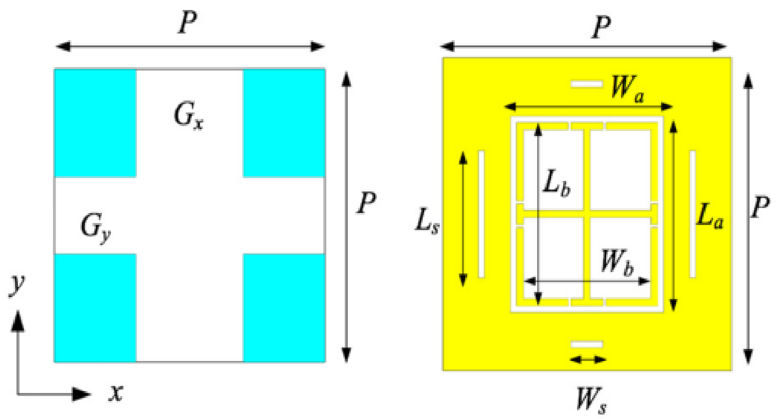


(c)

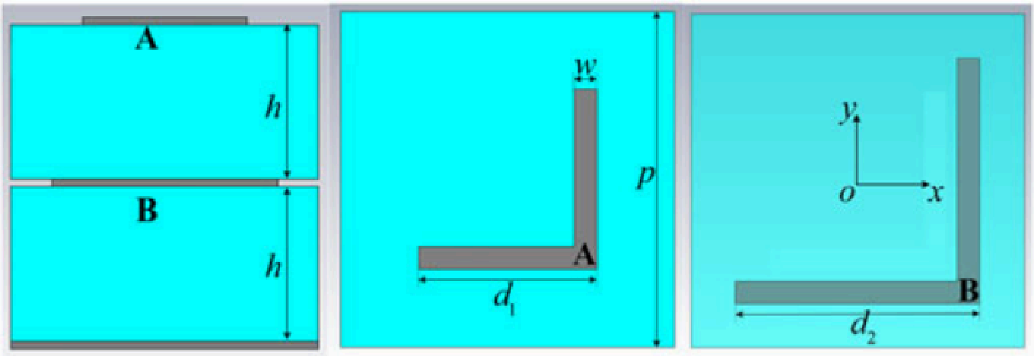
[13]This paper describes a novel concept of ultrathin linear to circular polarization converter by using a third-order meta frequency selective surface (meta-FSS) which operates in X-band. The meta surface consists of three metal layers which are separated by 2 dielectric substrates whose thickness is λ0/20. (Wavelength of λ0 is 9.8GHz the design achieves equal transmission coefficients in two orthogonal directions. While a 90° transmission phase difference between them over a broad bandwidth. Performance verification is conducted using a Horn antenna as a linear source. FSS converts the linear wave into left-hand circular polarized (LHCP) Which is at the range of 9.1-10.82GHz and the linear polarized wave turns into right-hand circular polarized (RHCP) wave in the range of 8.8 - 10.9 GHz.



(a)

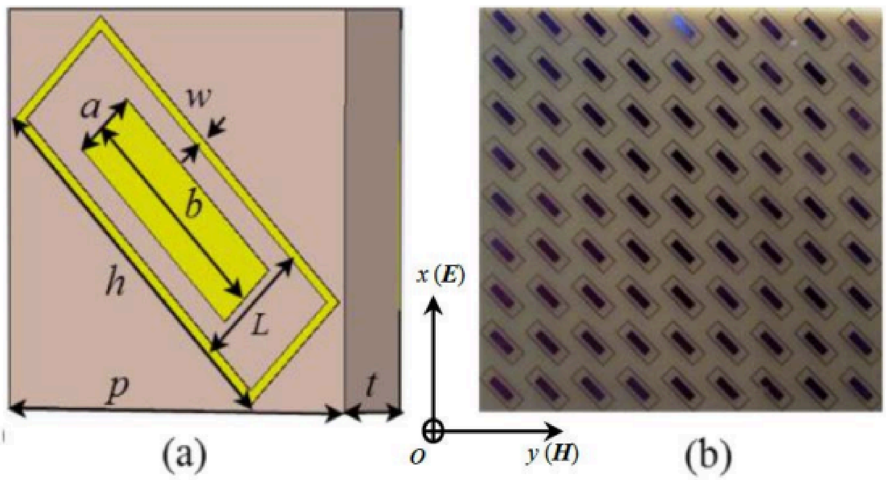


[14] In this paper, a double layered reflective metasurface is designed. The metasurface is composed of two layer metallic L-patterns. One L-pattern is etched on the first substrate and the other L is etched on Second substrate. When the incident angle is between 0 to 30°, the metasurface is regarded as a Three-band Reflective polarization convertor. On one hand the metasurface can convert the linear incident wave to right/left handed circularly polarized wave within 9.1 to 16.5 GHz and 20.0 to 25.4GHz. On the other hand it can do cross-polarization conversion between Transverse magnetic(TM) and Transverse Electric (TE) polarized waves from 17.4 to 18.9 GHz.



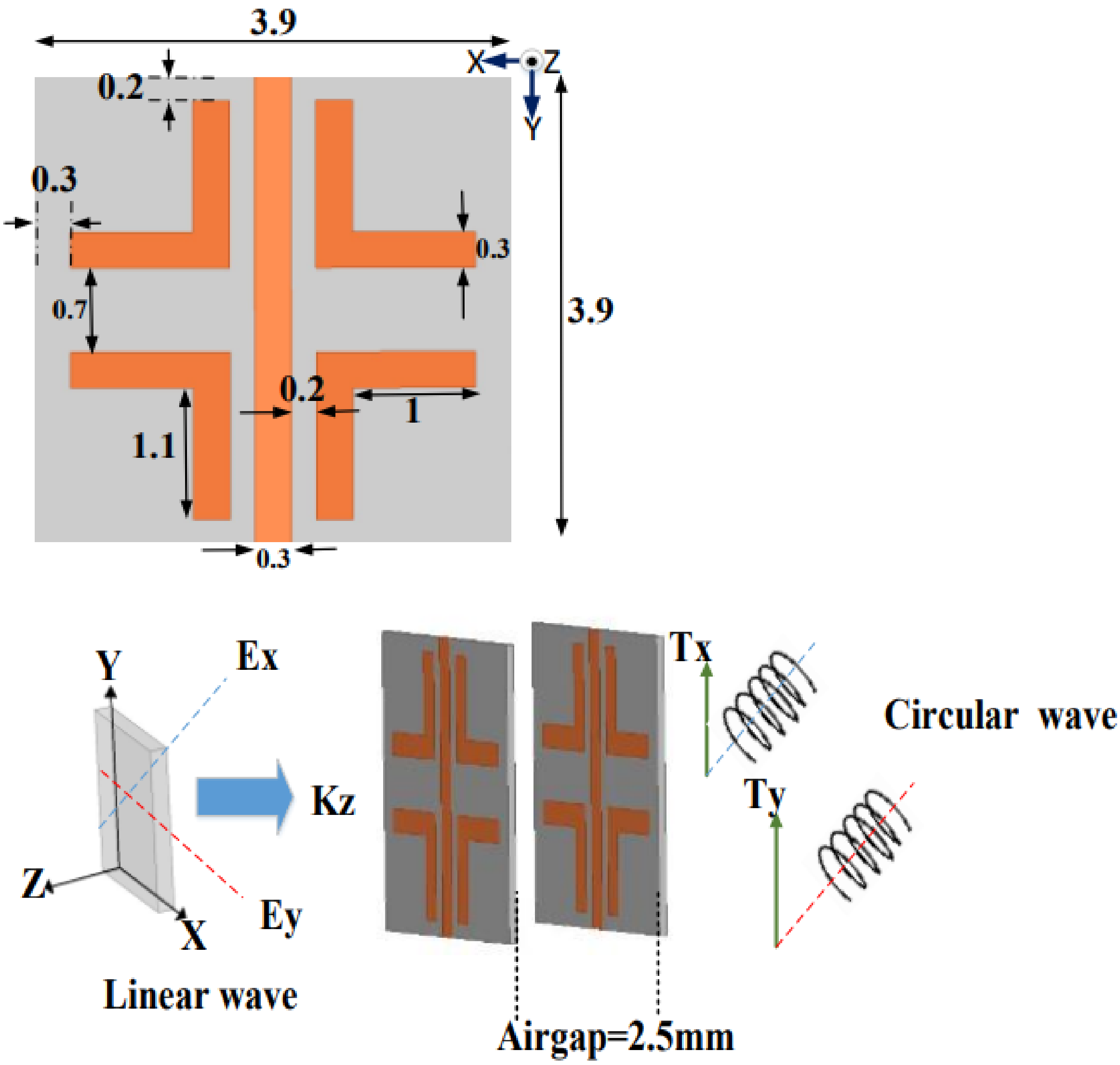
(a) (b) (c)

[15] A basic metasurface reflective polarization converter is proposed in this study. One unit cell consists of a concentric rectangular arrangement tilted in 45°. It is 15x15 unit cells periodically fabricated.The unit cell of top layer is composed of an inner metallic strip and outer rectangular ring tilted from x-axis in the xy plane. The metal sheet at the bottom acts as a reflector to eliminate transmission. This metasurface can convert the polarization of a linear incident wave to its orthogonal cross direction in two broad bands frequencies 4.40-5.30 GHz and 9.45-13.0GHz. This design can also convert linear to circular polarization without any losses in two frequency bands 4.47-5.35GHz and 9.57-13.57GHz. The polarization conversion efficiency is larger than 86% in this experiment.

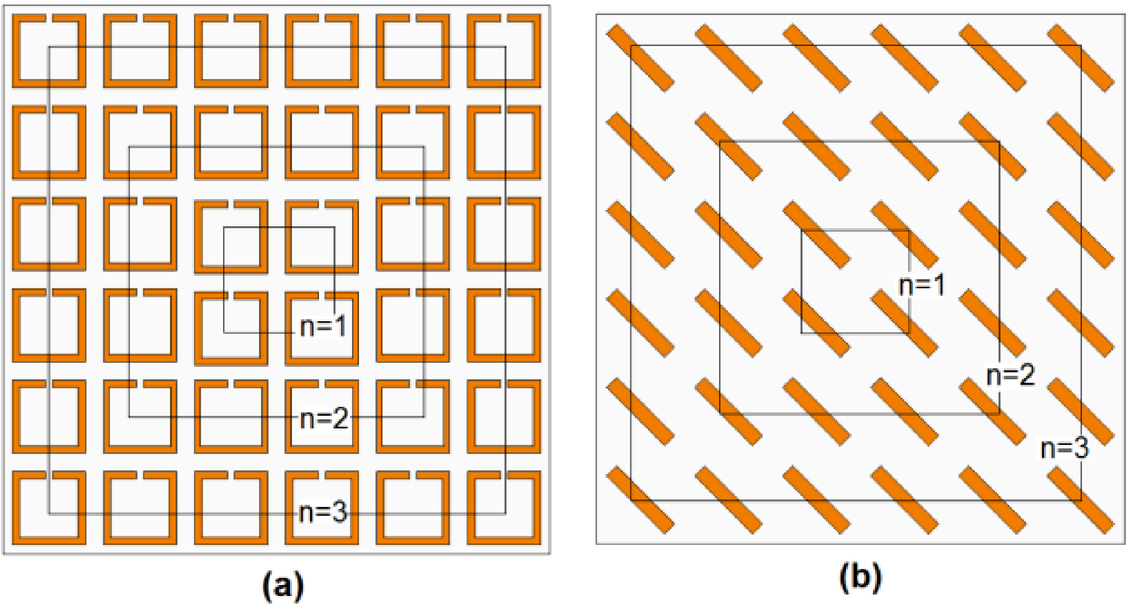


(a) (b)

[16]The paper talks about the two-layer linear to circular polarization which works for millimeter-wave applications using frequency selective surface (FSS). The polarizer splits the linear incident wave into two waves with equal amplitude but with 90° phase shift. Which produces a circularly polarized wave. The (FSS) works within the 28GHz to 33GHz frequency range. Simulation tells that the proposed polarizer maintains its performance with minimal sensitivity to oblique incident angle.

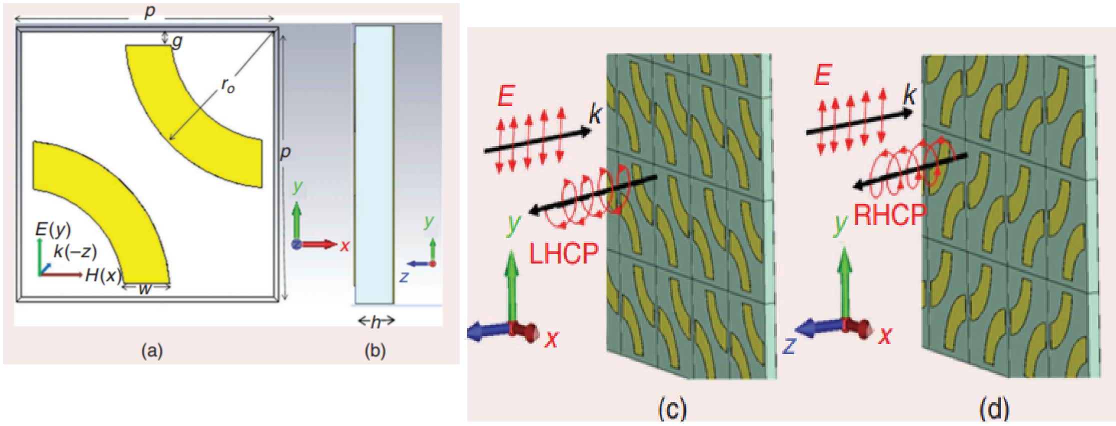


[17]The paper introduces a frequency selective surface (FSS) based polarizer designed to convert the linear polarization of the antenna into circular polarization. This polarizer works on two-layer structures with unit elements of different sizes. The lower layer is split ring resonators as unit elements and the upper layer consists of simple rotated dipoles. The polarizer is used as a reflector for coplanar waveguide (CPW). This polarization conversion works for dual bands. This polarizer has 3dB axial ratio bandwidths of 0.5GHz and 0.29GHz in boresight direction. The boresight gain of the antenna is increased by 4dB. The co-polarization to cross-polarization ratio increased by more than 15dB in the boresight direction in the both bands

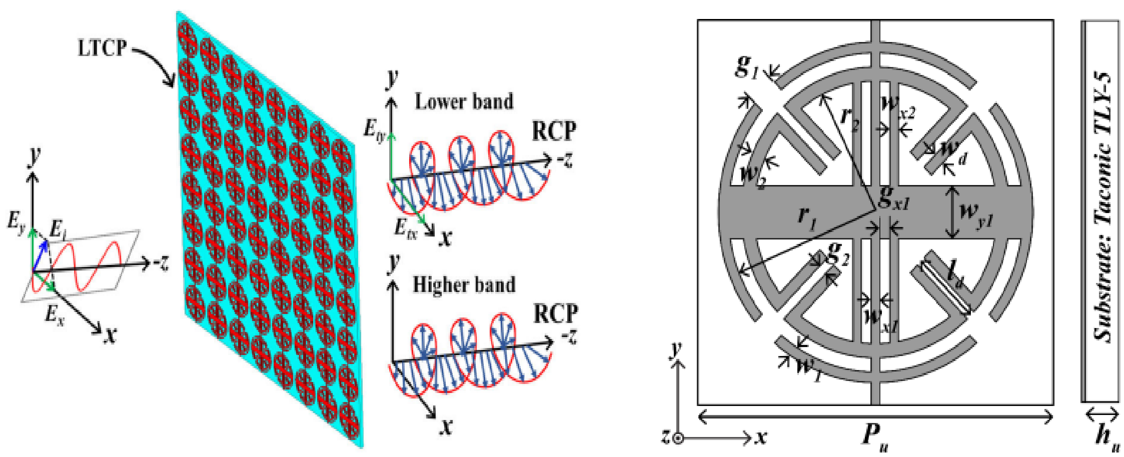


(a) Lower layer (b) Upper layer

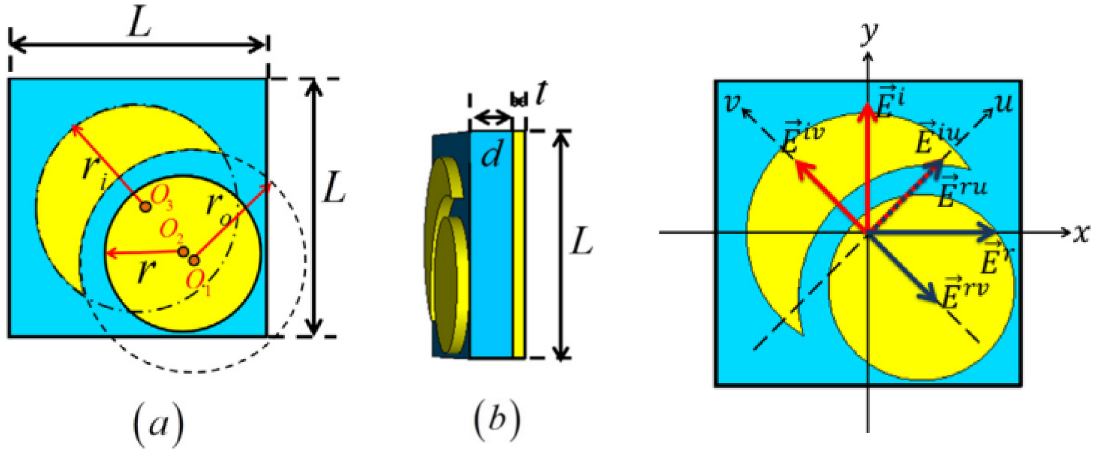
[18] This study is about an ultrathin reflective linear - to - circular polarization converter using metasurface. Linear to circular polarization is achieved in two distinct frequency bands 8.334 to 8.71 GHz and 10.3 to 14.73 GHz. In the former band, the structure converts linear to right-handed circular polarization(RHCP) converter, and in the latter it converts to left-handed circular polarization(LHCP). The unit cell structure is made up of two-quarter rings of width w=2.5mm and outer radii of 6.75mm, placed facing opposite to each other, concentric to two diagonal corners of a dielectric substrate.



[19]The paper introduces a dual-band transmissive linear-to-circular polarizer which is designed on a single layer, ultra-thin dielectric substrate. The unit cell of this converter consists of dual circular split rings and a centrally connected cross-grid dipole with the metal layer attached onto a 0.51 mm thick Taconic TLY-5 substrate. The converter converts the incident linearly polarized waves into circularly polarized waves at two distinct non-adjacent frequency bands, specifically in the X and K bands. The converter exhibits give an angle stability of 35°. The size of the designed converter is $0.2 \times 0.2 \times 0.019\ \lambda_L^{3}$ where λL is the wavelength at the center frequency of the lower band. The bottom metal layer serves as a ground plane in the lower band and as a reflector in the higher band to provide broadside radiation



[20] The design consists of a periodically arranged square split ring resonator, made by subtracting two circular segments and full circle. FR4 material is used as a substrate in the design. The metasurface converter operates in Ku frequency band range from 12.05 to 17.9 GHz for both linear to linear and circular to circular polarization with over 90% PCR.



(a) (b)

[21] The converter is made using a single layer of a material called a dielectric substrate and it consists of a metal strip cross backed by a strip horizontally and centrically located on the other metallic layer. The vertical part of the strip across the whole surface performs as a high pass filter with a wide passband above a low cutoff frequency on the other hand the horizontal strips interact with higher frequencies and also offers a wideband response below the resonant frequencies so it helps to achieve a wide range of frequencies. Another two short strips are added around horizontally and vertically to adjust the wave phase caused by the crosses and improve both the passbands. Using an ANSOFT HFSS an example of LCPC is designed with the overall size of 0.11λ0×0.21λ0 to achieve a 90-degree phase difference between two components of the wave which is necessary for converting a linearly polarized wave and circularly polarized wave. It maintains its performance over a wide range of angles. The prototype shows the simulated axial ratio over which AR stays below 3db is 69% and for measuring the range is 74% it performs well over a wide range of frequencies. Even when the wave hits at a 55% angle, the LCPC maintains an AR below 3db over 54% of the bandwidth for the oblique incident angle in the YZ plane. The design has low insertion loss of less than 3 and 2db which was measured over the entire bandwidth. The bandwidth where the AR is below 3db which keeps 70% and 55% which means 70% is for normal incidence and 55% is for oblique incidence.

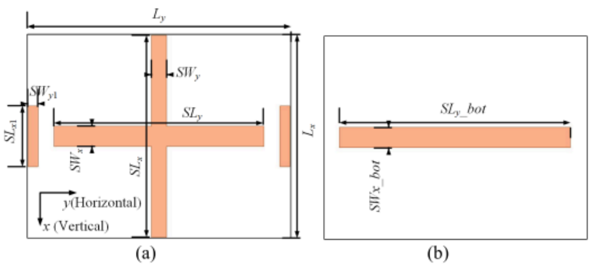
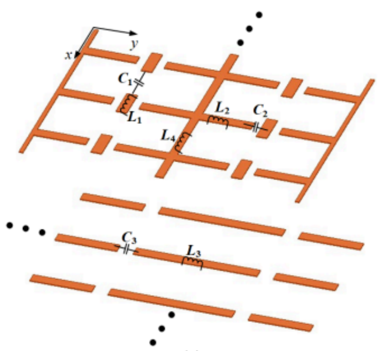


Fig. 1. Configuration of the proposed LCPC element. (a) Top layer. (b) Bottom layer. $L_x = 1.4$, $L_y = 2.6$, $SL_x = 1.4$, $SL_{x1} = 0.6$, $SL_y = 2.08$, $SL_y\_bot = 2.3$, $SW_x = 0.2$, $SW_x\_bot = 0.2$, $SW_y = 0.15$, and $y_1 = 0.1$ (unit: mm).



(a)

[22] it is the study of a multifunctional, reconfigurable meta surface made from a flexible material that uses liquid metal injection for switching between different configurations. The meta surface consists of two microfluidic layers: the top layer and the bottom layer. The top layer has an array of meandered half rings and the bottom layer has straight meander lines. When the channels are empty, the meta surface acts like a reflector. In the polarization conversion when the top layer is filled, the meta surface converts linearly polarized waves into circularly polarized waves and when the bottom layer is filled it converts linearly polarized waves into cross-polarization waves . For cross-polarization conversion, it operates over the 9.83 to 17.42 GHz range with a 53% bandwidth and a polarization conversion ratio (PCR) of at least 90%. For linear-to-circular polarization conversion, it operates over the 8.97 to 11.30 GHz range with a 23% bandwidth. After being performed and tested a verification of a 25 × 25 element metasurface array was fabricated and tested, with experimental results matching the simulations in the 8–12 GHz frequency range.

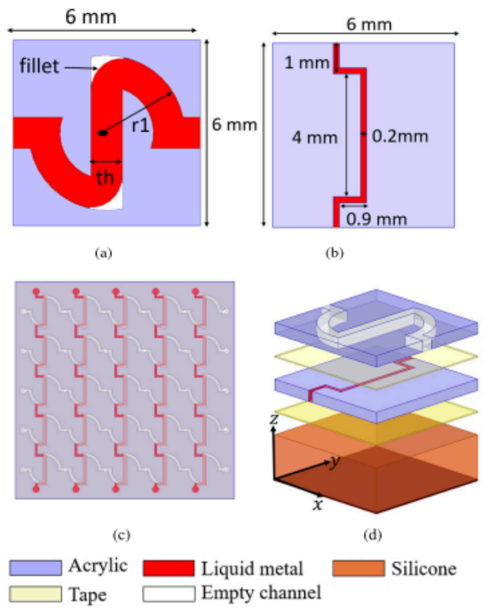
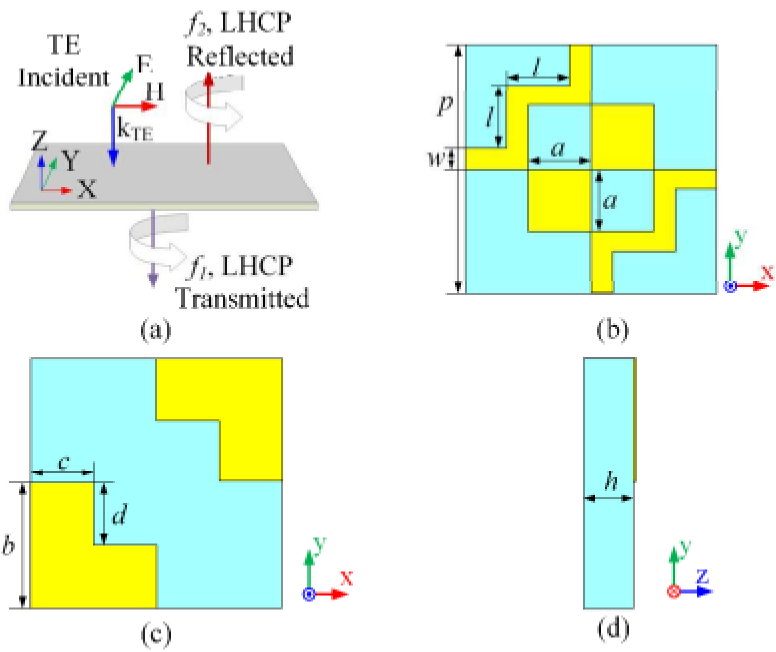
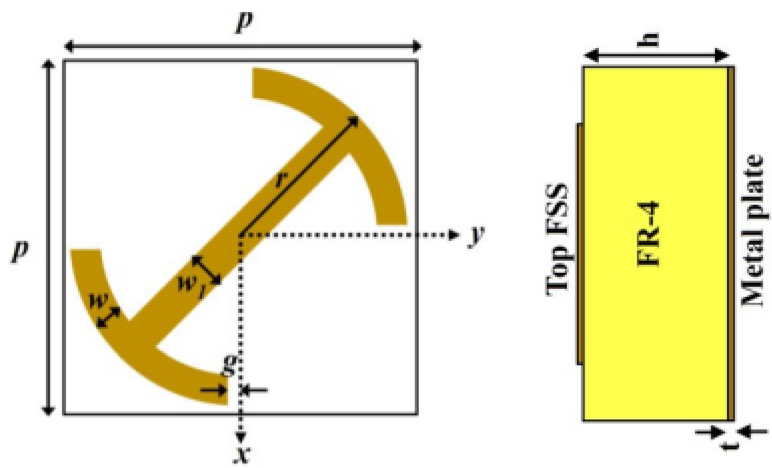


Fig. 1. Geometry of the microfluidic metasurface (to go along with Table I). (a) Unit cell of top layer for linear-to-circular polarization. (b) Unit cell of bottom layer for linear-to-cross polarization. (c) Top view. (d) 3-D stackup of the unit cell.

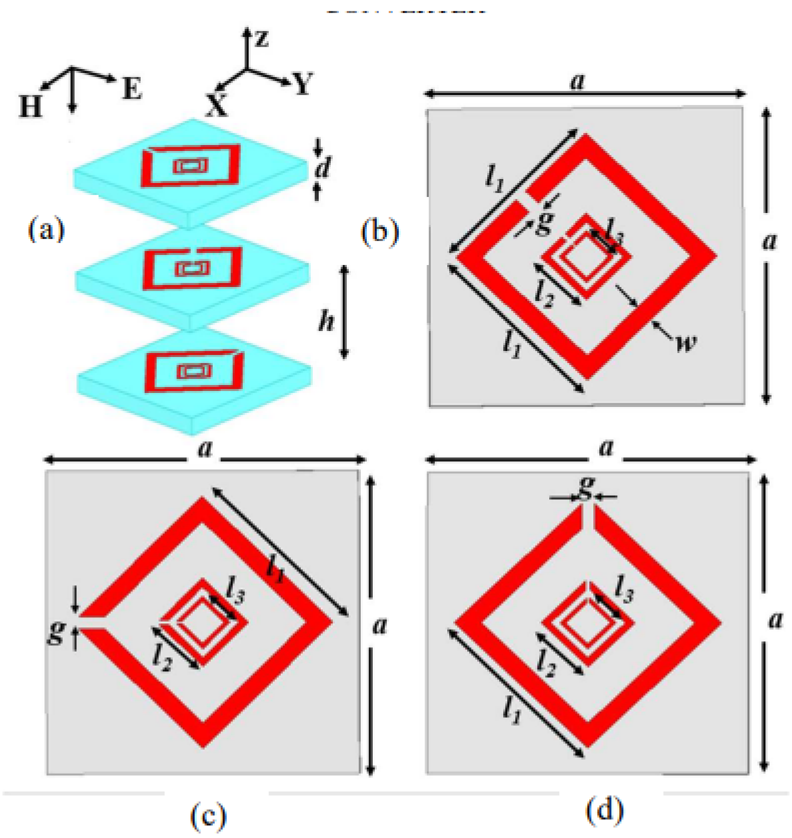
The paper presents the metasurface that is specially designed surface that can achieve linear to circular polarization which makes this metasurface unique in its ability to perform this polarization conversion in both transmission and reflection modes.the metasurface is made of two metallic layers on an ultrathin substrate with a thickness of 0.0794λ0 operates around 23.82Ghz. The proposed linear to circular polarization achieves a 3db axial ratio of bandwidth[ARBW] of 7.8555% (from 22.87 to 24.74 Ghz) for transmission and 12.88%(from 29.42% to 33.47Ghz) for reflection. It is capable of reflecting peak circular co-polarized power of 55.2% and 85.5% respectively of the incident wave . additionally it can convert TE-polarized incident wave into left handed circularly polarized wave (LHCP) and TM - polarized wave into right handed circularly polarized wave in both transmissions and reflections modes. An equivalent circuit model is also provided to explain the working mechanism of the proposed LCPC.



The study introduced a wideband angular stable polarization converter design for both linear cross and linear circular polarization conversion. The unit cell consists of a 45 degree rotated circular arc based I shaped resonator printed on Top of a thin FR4 grounded dielectric substrate. The proposed meta surfaces can convert YX squared incident waves into three different frequency ranges. C,X and KU bands. Additionally, it can convert linearly polarized waves into circular polarization in the C and KU bands. along with linear orthogonal conversion, the polarization response remains stable. up to 45 degrees For linear cross conversion and up to. 30 degrees for linear circular conversion for both. TE and TM Oblique incidences. The design is unique for its dual polarization conversion. capability within the same frequency bands and its compactness with periodicity of 0.1539λl & 0.0535λl (Where Lambda L refers the longest free space wavelength in the operational band) The authors believe that design has strong potential for real world applications where the dual polarization conversion,both linear and circular is a key requirement.



The paper presents a transmitter type dual band Linear to circular polarization converter. The design is capable of converting an incident linearly polarizer given into a right handed circular pole ratio in two non adjacent frequency ranges within the C and KU bands. It features a tri-layer configuration consisting of three concentric square-shaped, split ring resonators with slits oriented at 45 degrees relative to each other. The results from simulation indicate that the axial ratio of the proposed converter remains below 3DB across the frequency range of 4.07 -- 4.15 GHz and 14.19 -- 14.51 GHz . .The ellipticity values of the structure are -0.98 and -0.99 at 4.1 GHz and 14.3 GHz, respectively, confirming the right-handed CP nature of the transmitted wave.This transmittiive-type metasurface can be easily mounted onto a simple dual-band LP antenna to achieve the desired dual-band CP wave for satellite communication systems.The structure has a periodicity of λ/5 and maintains a thickness of λ/6.6 with respect to the center frequency of the first conversion band.



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[22] Reconfigurable Polarization Converter Using Liquid Metal Based Metasurface

[23]Simultaneous Transmission and Reflection Mode Linear-to-Circular Polarization Conversion Using a Single Metasurface

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[25] A Transmittive-type Metasurface for Dual-band Linear to Circular Polarization Conversion

Altering the polarization of an EM wave finds applications in the reflect array used in satellite communication, reducing the detectability of the radar termed as RCS reduction, converting a linearly polarized antenna to circular polarized thereby reducing the feeding and design complexity. For all these applications planar surfaces were more suitable to convert the polarization of an EM wave both in transmission and reflection mode. These surfaces are technically called polarization converters. Conventional techniques used suffer from challenges of design as they are not suitable for compact environments.

With the evolution of metamaterials, the exotic properties they possess lead to the development of several applications. Few of them are electromagnetic wave absorption achieved by tuning complex permeability and permeability, polarization conversion achieved by controlling electric and magnetic resonances which leads to controlling of surface currents. Therefore metasurfaces have turned to be used as an alternative medium to convert the polarization of EM waves for suitable applications.

Metasurfaces are highly suitable for polarization conversion due to their ability to precisely manipulate electromagnetic waves at the sub-wavelength scale. These artificially constructed periodic resonant structures can be designed to control the amplitude, frequency, phase, and polarization of incoming waves. Their customizable nature allows them to efficiently convert the polarization state of electromagnetic signals, such as from linear to circular polarization, which is essential for applications like satellite communications and radar systems.They are an excellent option for polarization conversion in both civilian and military technologies since they are also inexpensive to create, lightweight, and adaptable to specific needs.

The development of polarization converters has been significant, because of the need to address the various challenges in communication systems, like polarization mismatches between transmitters and receivers. Initially, single-band polarization converters were designed to convert linearly polarized EM waves into circularly polarized waves within specific frequency bands. Many single band PCs are designed in this way; some of them have wideband converters that can handle both linear-linear and linear-circular conversions. In one design, an I- shaped resonator with 45-degree rotational arc based on FR4 grounded dielectric substrate was made, enabling polarization conversion in multiple bands like C,X and Ku. The limitations of single-band PCs, which were confined to specific frequency ranges led to the evolution of dual-band polarization converters. The development of dual-band reflective linear-to-circular polarization converter based on metasurface was an important advancement.The design is combined with a square patch and an open ring within its unit cell. As a result, it could transform LP waves into right-handed circularly polarized (RHCP) and left-handed circularly polarized(LHCP), depending on incident direction. Dual-band converters remain unable to cover an even wider range of frequencies,hence multiband converters came into picture.

Traditionally Advances in metasurface technology have led to the development of multi-band and reconfigurable polarization converters, which provide more advantages than their single-frequency band counterparts. While dual-band designs extend functionality across two frequency bands by utilizing resonant structures like square patches and open rings, single band converters use metasurfaces with unit cells to achieve high polarization conversion ratios with specific frequency ranges. By enabling polarization conversion across numerous frequency bands, multi-band converters further increase capabilities and are appropriate for intricate communication systems. Adaptable transformers, utilizing substances such as liquid crystals, The transition from single-band to multi-band and reconfigurable designs is indicative of the increasing need in contemporary technology for polarization manipulation solutions that are portable, effective, and adaptable.