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Single Feed Circular Polarized Circular Patch Antenna with C – Shaped Slots for Mobile Applications

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ABSTRACT

A single feed circularly polarized c-shaped and circular patch antenna with improved axial ratio bandwidth is presented. In this article, both c-shaped slots and circular patch antenna were designed and by using the concept of switches like PIN diodes the circular polarization have been obtained. In this article the circular polarization was achieved by creating some asymmetry in the structure of an antenna. The performance characteristics of an antenna were explained in terms of its return loss characteristics and elevation radiation pattern of gain by using IE3D simulator.

I.Introduction

The application of polarization diversity can be obtained in the design of c – shaped and circular patch antenna is a recent technique to get the benefits of compact size, high bandwidth, multiband operation, etc. There have been a number of research articles available on polarization diversity to design microstrip patch antennas for the last one decade. An excellent review on polarization diversity antennas is given by D. H. Schaubert and S. T. Hayes in [1]. The behavior of circular patch antenna is to meet low cost, high performance. After thoroughly going through the literature, it is observed that the circular patch and c - shaped slot antenna can be used to obtain circularly polarization because of its geometrical flexibility.

Many articles are available in the open literature on single feed circularly polarized microstrip antennas. The simplest and foremost single feed circularly polarized microstrip antenna is reported by Sharma and Guptha [2] using a nearly square patch and truncated square patch antennas. Circularly polarized single Fed wide band microstrip antenna is reported by Naftali Herscovici et al. [3] with 3 dB axial ratio bandwidth of 13%. Wong and Lin [4] presented a circularly polarized microstrip antenna with tuning stub to a circular patch having the 3 dB axial ratio band width of about 0.9%. A compact single feed circularly polarized circular patch antenna with crossed slots on both radiating patch and ground plane is reported by Row and Ai [5] with 3 dB axial ratio bandwidth of around 1%. A novel compact circularly polarized square microstrip antenna is reported by Chen et al. [6] with 3 dB axial ratio bandwidth of about 0.8%. A single feed square ring microstrip antenna with truncated corners for compact cp operation is presented by Chen et al. [7] with cp bandwidth around 1.3%.

In this article, a novel technique is adopted to obtain circular polarization using PIN diode switches to the c - shaped slots and circular microstrip patch antenna.

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II. Dimensions of circular patch and c – shaped slots

Other than the rectangular patch, the next most popular configuration is the circular patch or disk. It also have lot of attention not only as a single element [8], but also in arrays [9]. The modes supported by the circular patch antenna can be found by treating the patch, ground plane, and the material between the two as a circular cavity. For the circular patch there is only one degree of freedom to control radius of the patch. Doing this does not change the order of the modes, but it does change the absolute value of the resonant frequency of each.

The circular patch antenna can only be analyzed conveniently using the cavity model [10]. The cavity is composed of two perfect electric conductors at the top and bottom to represent the patch and the ground plane, and by cylindrical perfect magnetic conductor around the circular periphery of the cavity.

The resonant frequency and radius of the circular patch antenna is represented as given in equation (1) and (2) given below:

$$f_r = \frac{1.8412 v_0}{2\pi a_e \sqrt{\varepsilon_r}} \quad (1)$$

$$a = \frac{F}{\{1 + \frac{2h}{\pi \varepsilon_r F}[\ln(\frac{\pi F}{2h}) + 1.7726]\}^{1/2}} \quad (2)$$

Where, $$F = \frac{8.791 \times 10^9}{f_r \sqrt{\varepsilon_r}} \quad (3)$$

Fig 1. represents the design of Circular patch antenna with probe feeding shown below:

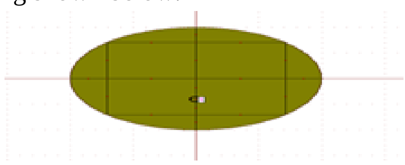


Fig 1. Circular patch antenna with probe feeding.

Based on the above equations in this article the circular patch antenna was designed with a radius of a = 10 mm, permittivity of a material εr = 2.2, thickness of a substrate = 3.2 mm and loss tangent tanδ = 0.0009. The circular patch antenna was fed with a probe feeding. In the next step the circular patch antenna was designed with C-shaped slots on both sides of a patch. Circular polarization can be obtained using various feed arrangements or slight modifications made to the elements. Circular polarization can be obtained if two orthogonal modes are excited with a 90º time-phase difference between them. This can be accomplished by adjusting the physical dimensions of the patch and using either single, or two or more feeds. There have been some suggestions made and reported in the literature using single patches [10].

For a circular patch, circular polarization is achieved by using two feeds with proper angular separation. Using two coaxial feeds separated by 90º which generate fields that are orthogonal to each other under the patch, as well as outside the patch. Also with this two probe arrangement, each probe is always positioned at a point where the field generated by the other probe exhibits a null; therefore there is very little mutual coupling between the two probes. Circular polarization can be obtained by two methods. In the first method feeding must be provided at the diagonal of the patch element whereas in the second method if some asymmetry was created in the structure by using the concept of switches like PIN diodes and MEMS. So in this article the circular polarization was obtained by using the concept of switches like PIN diodes.

III. Circular polarization operation with circular patch and c-shaped slot antenna

In this article the circular polarization was obtained by using the concept of switches like PIN diodes [11]. On both sides of the patch antenna c-shaped slots were designed and these slots are connected to the circular patch antenna through by using PIN diode switches. It means for the structure some asymmetry had created and there by obtaining circular polarization diversity [12]. In this article both left hand and right hand circular polarization was achieved by making the switches ON and OFF, OFF and ON respectively.

1. Linear polarization with OFF and OFF condition

Fig 2. presents the design of circular patch antenna with c-shaped slots and no PIN diode switches were connected.

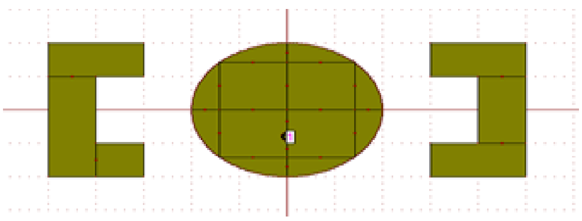


Fig 2. Design of Circular patch antenna with c-shaped slots and two switches are in OFF condition

The c-shaped slots were connected to the circular patch by using two PIN diode switches, so this article presents totally four cases of operations as 2n, where n indicates number of switches [13]. If the axial ratio of an antenna is 1 or in the radiation pattern if the component of E-theta at Φ = 0º is towards left or towards right, than it represents left hand circular polarization (LHCP) and right hand circular polarization (RHCP) respectively.

The below fig 3. represents the return loss characteristics of circular patch antenna and the two PIN diode switches were in OFF condition. The operating frequency of an antenna was 5.28 GHz and its return loss characteristic S11 = -26.49 dB.

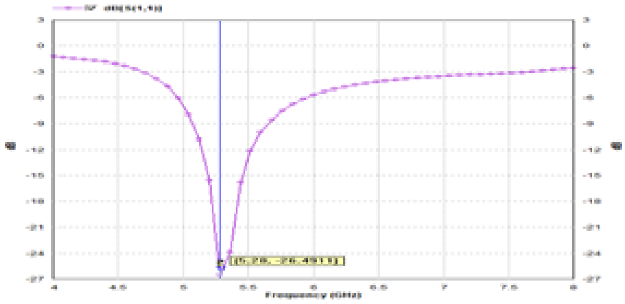


Fig 3. Return loss characteristics (S11) of antenna with OFF and OFF condition

The below fig 4. represents that E-theta at Φ = 0º obtained the linear polarization, because E-theta component on both left and right side were having equal magnitude components since the structure of required antenna was in symmetry condition.

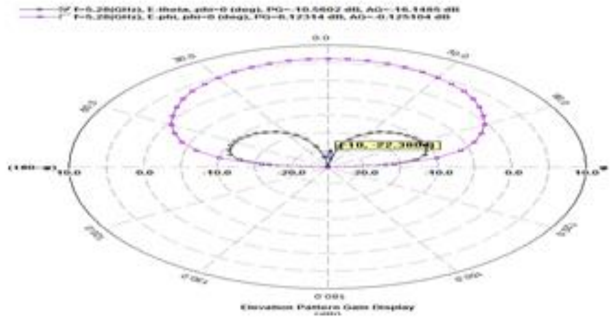


Fig 4. Elevation of radiation pattern of gain at Φ = 0º of antenna with OFF and OFF condition.

The above fig 4. represents that E-theta at Φ = 0º obtained the linear polarization, because E-theta component on both left and right side were having equal magnitude components since the structure of required antenna was in symmetry condition.

2. Left hand circular polarization with ON and OFF condition

Fig 5. presents the design of circular patch antenna with c-shaped slots and switches were connected as ON and OFF condition.

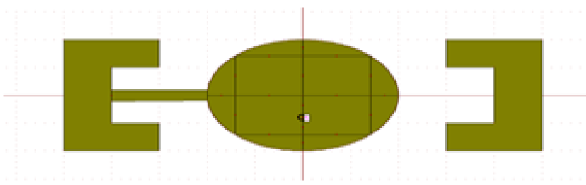


Fig 5. Design of Circular patch antenna with c-shaped slots and switches were connected as ON and OFF condition

In the above fig 5. some type of asymmetry was created in the structure of an antenna by keeping PIN diode switch S_1 in ON condition and switch S_2 is in OFF condition [14]. In the below fig 6. represents the return loss characteristics of circular patch antenna and switches were connected as ON and OFF condition. The operating frequency of an antenna was 5.35 GHz and its return loss characteristic S_{11} = -25.51 dB.

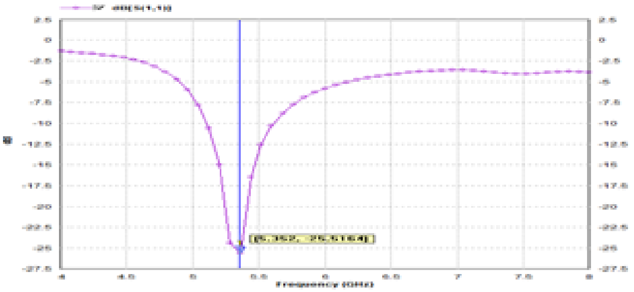


Fig 6. Return loss characteristics (S_{11}) of an antenna and switches were connected as ON and OFF condition.

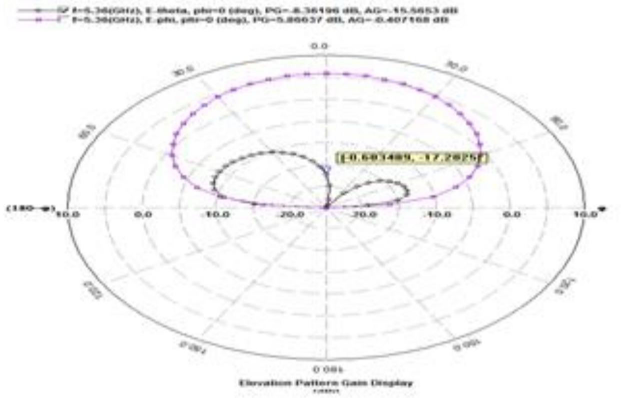


Fig 7. Elevation of radiation pattern of gain at Φ = 0º of an antenna and switches were connected as ON and OFF condition.

In the above fig 7. E-theta component at Φ = 0º is towards left, so it represents left hand circular polarization (LHCP).

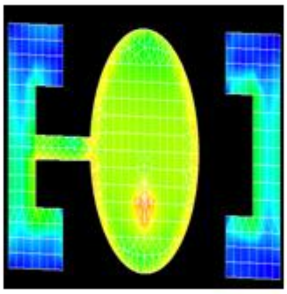


Fig 8.1. Current distribution pattern of an antenna and switches were connected as ON and OFF condition

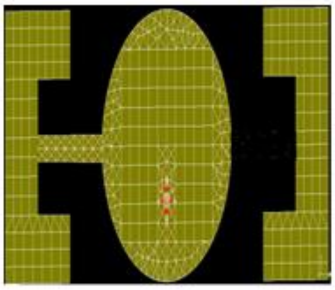


Fig 8.2 Vector distribution pattern of an antenna and switches were connected as ON and OFF condition

3. Right hand circular polarization with ON and OFF condition

Fig 9. presents the design of circular patch antenna with c-shaped slots and switches were connected as OFF and ON condition.

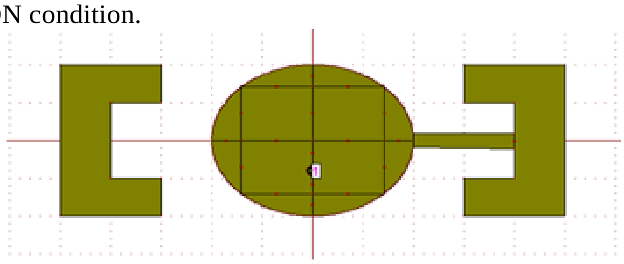


Fig 9. Design of Circular patch antenna with c-shaped slots and switches were connected as OFF and ON condition

In the below fig 10. represents the return loss characteristics of circular patch antenna and switches were connected as OFF and ON condition. The operating frequency of an antenna was 5.36 GHz and its return loss characteristic S_{11} = -25.61 dB.

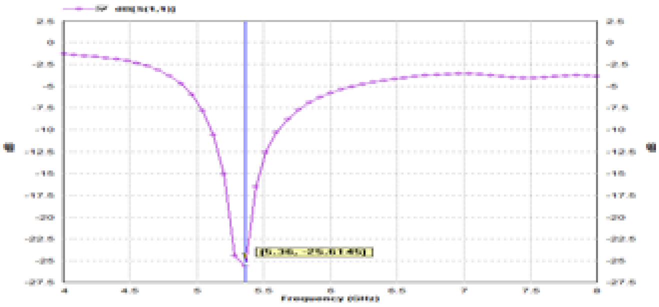


Fig 10. Return loss characteristics (S_{11}) of an antenna and switches were connected as OFF and ON condition.

In the below fig 11. E-theta component at Φ = 0º is towards right, so it represents right hand circular polarization (RHCP).

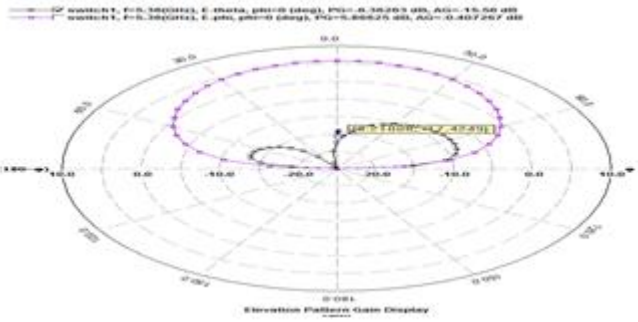
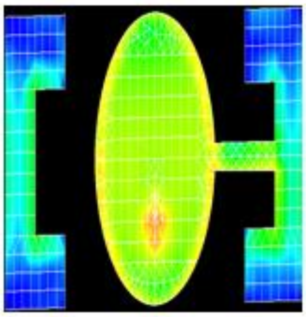


Fig 11. Elevation of radiation pattern of gain at Φ = 0º of an antenna and switches were connected as OFF and ON condition.



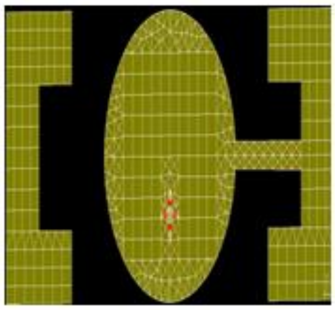


Fig 12.1. Current distribution pattern of an antenna and switches were connected as OFF and ON condition

Fig 12.2 Vector distribution pattern of an antenna and switches were connected as OFF and ON condition.

4. Linear polarization with ON and ON condition.

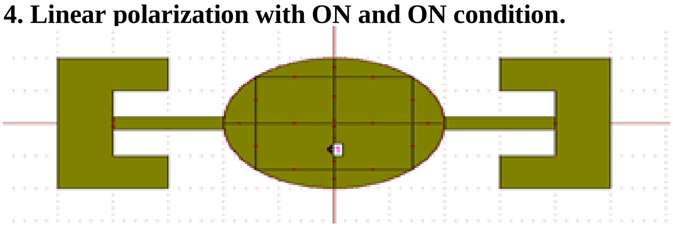


Fig 13. Design of Circular patch antenna with c-shaped slots and switches were connected as ON and ON condition

In the above fig 13. the two PIN diode switches were connected so it is creating symmetry in the structure of an antenna which results in linear polarization.

In the below fig 14. represents the return loss characteristics of circular patch antenna and switches were connected as ON

and OFF condition. The operating frequency of an antenna was 5.36 GHz and its return loss characteristics S_{11} = -25.00 dB.

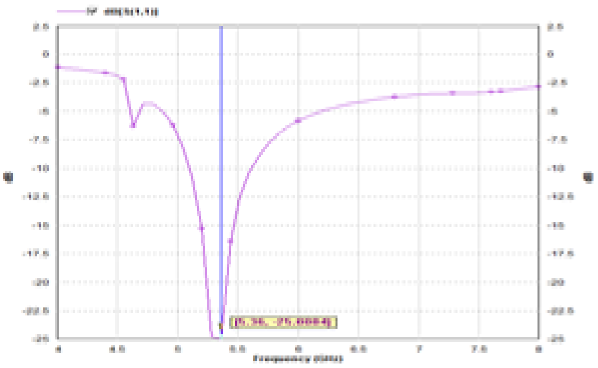


Fig 14. Return loss characteristics (S_{11}) of an antenna and switches were connected as ON and ON condition.

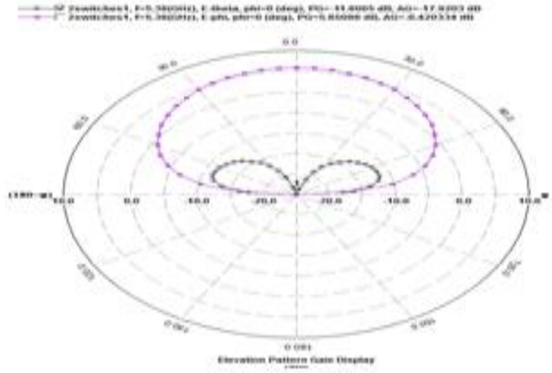


Fig 15. Elevation of radiation pattern of gain at Φ = 0° of antenna with ON and ON condition.

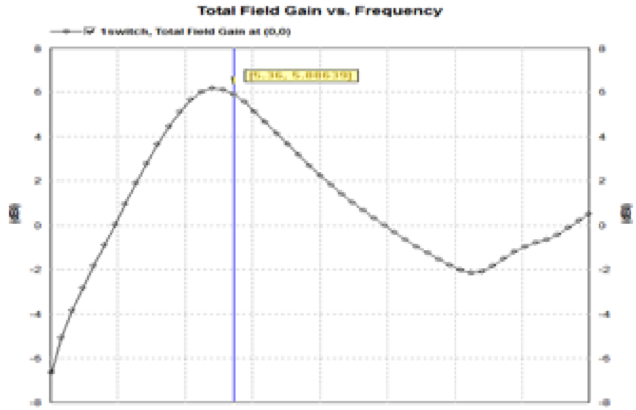


Fig 16. Plot of Gain Vs Frequency of circular patch antenna with c-shaped slots.

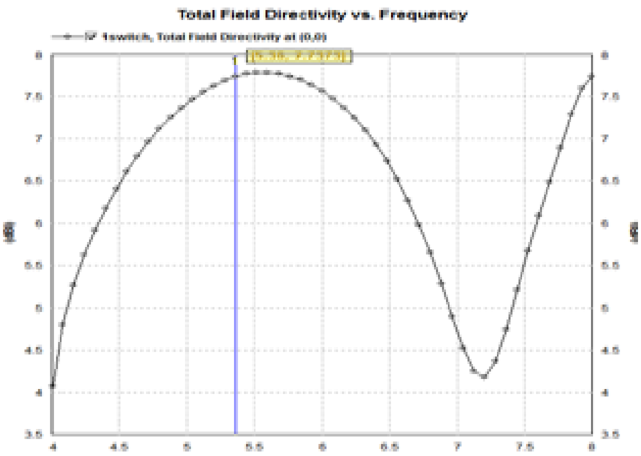


Fig 17. Plot of Directivity Vs Frequency of circular patch antenna with c-shaped slots.

Table I. Performance characteristics of circular patch. antenna with c-shaped slots of different cases.

[1] **Antenna Parameters**	[2] **Cases**			
	• ***Case A***	• ***Case B***	• ***Case C***	• ***Case D***
Operating Frequency (GHz)	5.28	5.35	5.36	5.36
Return Loss (dB)	-26.59	-25.51	-25.61	-25.00
Bandwidth (GHz)	0.4	0.5	0.55	0.38
Antenna Gain (dBi)	5.14	5.22	5.24	5.08
Polarization	LP	LHCP	RHCP	LP

Conclusion

By using the reconfigurable antenna we can achieve frequency and polarization diversity In a single antenna instead of using multiple antennas for different applications. We can extend this concept by incorporating different switching configurations like MEMS, and also we can increase the number of switches in order to get more frequency bands.

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