Design and Performance Studies of an Elliptical Slot Circular Polarization Antenna for C-Band Wireless Applications

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***Abstract*— A novel and subtle design of a circularly polarized microstrip line feed elliptical slot monopole antenna with an intention to use in C-Band (4-8 GHz) is proposed in this communication. Due to notable as well as remarkable performances, this small and compact antenna with ample applications in the arena of wireless communication upholds its strong position among the previous work of similar types. For designing and simulating the proposed antenna for exploration of its feasibility to use in the C-band wireless applications especially satellite-based communication system, CST MW studio is used. Different categories of calculations and performance studies have been performed while maintaining a suitable environment of free space for wireless communication. The antenna with overall dimension of 50 mm × 30 mm × 0.836 mm, where the substrate is used is Teflon and Copper is used as radiating patch as well as ground plane, is placed for evaluating its performance in respect of return loss, radiation and total efficiency, VSWR, gain, directivity, direction of surface current, axial ratio (AR) bandwidth, and reduction of cross polarization (XP). An impressive return loss (-41.7 dB) at the resonance frequency and suppression of XP of 33.50 dB have been accomplished with other marvelous results.**

Keywords—circular polarization, elliptical slot, monopole, microstrip line-fed, AR bandwidth , satellite applications.

I. Introduction

Circular polarization (CP) antennas are extensively used in satellite applications because of the improvement of the immunity to multipath distortion as well as reduction of polarization mismatch losses compared to the linear polarization (LP) antennas [1]. Furthermore, CP offers some extra advantage in the transmitting and receiving antenna and extenuation of the effect of weather condition for radar and satellite communication [2]. Consequently, in recent years, to find the utmost polarization efficiency, application of CP for the antenna has been alluring devotion [3]. Notwithstanding of advantage, due to consideration of the requirement of both the impedance bandwidth and the axial ratio (AR) bandwidth, it is more challenging to realize wide bandwidth in CP antennas compared to LP antennas. Usually, reduction of available bandwidth for CP antenna happening due to the AR bandwidth of CP antennas is narrower than impedance bandwidth [4].

With technological advancements in RF and microwave arena, complex circuitry unified design, miniaturized and improved performance have become acquainted in recent years. With significance accessibility in the arena of a wireless system, antennas have been frequently integrated into simple devices [5]. Because of the advantages of a simple and effective structure, lightweight, wide bandwidth and good radiation efficiency, monopole antennas have captured the attention of many antenna designers. Variations in design of monopole antennas for producing CP, have also been proposed in recent years. With both LP and CP, a CPW-fed antenna monopole in nature was reported in the literature [6]. In [7], wideband and CP performance were consummated with the introduction of an inverted-L strip and asymmetrical ground plane. Still, above mentioned antennas practically have narrow AR bandwidths. A shape of Y unequal arms monopoly antenna for production of CP is proposed in [8]. A monopoly L-shaped antenna [9] has been proposed with the intention of enhancement of AR bandwidth. Furthermore, an asymmetric feed rectangular shaped monopole antenna [10] with accomplishment of 34.2% AR bandwidth as well as a monopole power division network feed antenna [11] with the achievement of 30% of bandwidth of AR have been projected. The limitations caused by the bidirectional patterns have been mentioned in the literatures [7]-[11].

An introduction of unidirectional CP antennas with the help of a back reflector in the arena of communication system of point-to-point for elimination of the back radiation is accomplished with a large size as well as narrow CP bandwidth [12]-[13]. A C-shaped CP antenna designed by placing rectangular open-loop coupled in monopole as well as a rectangular stun in the ground with result of wide impedance of 87.7% and AR bandwidth of 65.2% is presented in [14].

Defected ground structure (DGS) in microstrip antenna was established in 2005 for reducing the radiations of cross-polarization (XP) through a lot of works [15]. Reasonable setups of the DGS have been investigated for diverse fix geometries in [16]-[22]. All geometries inspected so far were naturally symmetric and weaken idea for the first higher mode. An asymmetrically shaped DGS with a development in terms of size and performance characteristics compared to the former version is proposed the first time in [23].

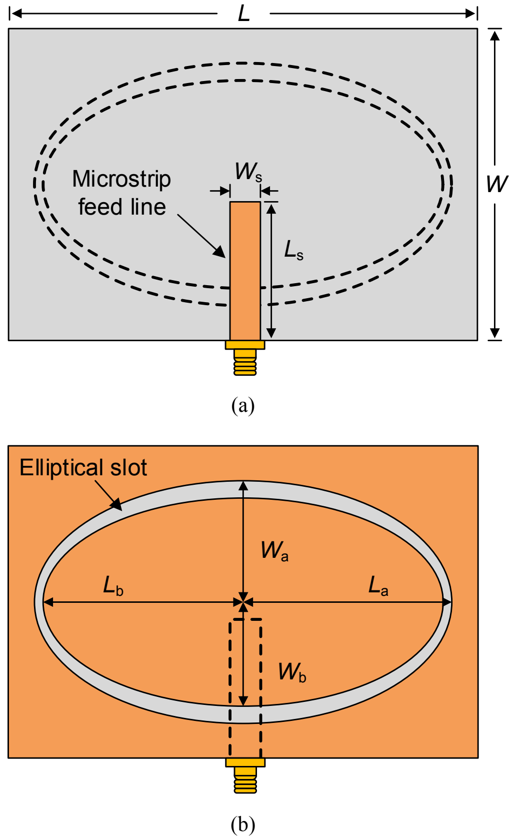


Fig. 1. Geometric structure of the proposed antenna. (a) Top view. (b) Bottom view.

According to the different applications, "Frequency Ranges" or "Bands" are allocated by the international organizations bearing purpose of transmitting as well as receiving signals throughout of the world. C-band is used for communication purpose by many satellite-based wireless applications, WiFi devices and also some other radar system [24]. Various different shapes and feeding techniques for designing CP antennas to use in C-Band are illustrated by the upcoming references. An innovative dual CP monopole printed broadband antenna using orthogonal feed lines is proposed for using in the application field of C-Band along with quite a good gain, port isolation and AR bandwidth in [25]. The research [26] proposed a compact design antenna with a horizontal stub in the middle of the wide slot from the ground plane. A patch antenna with excitation by four cross slots is designed to achieve broadband dual CP. An increase in the bandwidth of AR has been achieved through this excitation technique in the proposed antenna [27].

On considering all this information into an account, in this communication, a microstrip monopole elliptical slot antenna with remarkable impedance matching of −41.7 dB with quite good impedance bandwidth as well as CP bandwidth is proposed. A Teflon substrate with thickness of 0.8 mm and Copper as patch and ground are used for designing the antenna while the total dimension is 50 mm × 30 mm × 0.836 mm. More than 32 dB suppression in XP with approximately equal AR and impedence bandwidth which is 690 MHz is achieved. With marvelous gain as well as directivity and radiation pattern in the total area of AR bandwidth and subtle design creates a place over the previous work in related field.

Organization of rest of the article is as follow: section II is populated with antenna design and parametric analysis.

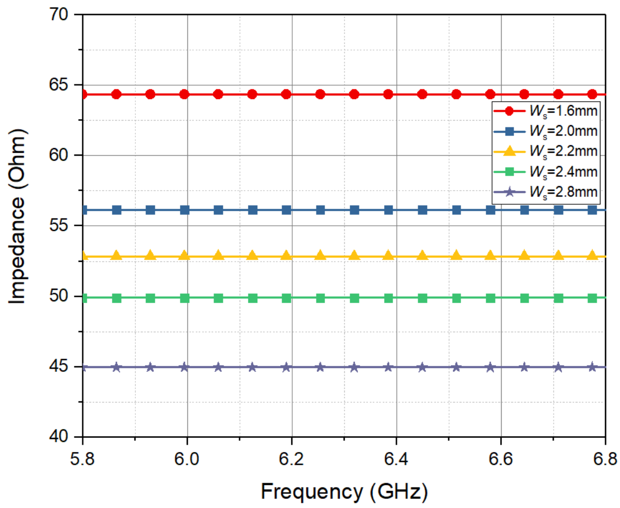


Fig. 2. Impedance variation for different values of W_s.

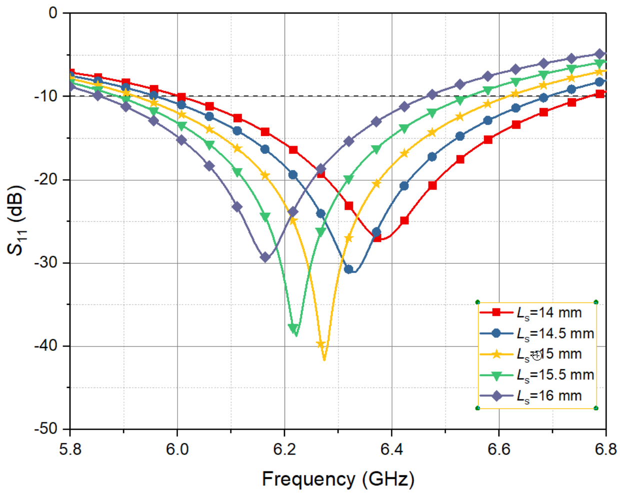


Fig. 3. S_{11} for different values of L_s.

Section III covers the performance studies and discussion on antenna characteristics. Conclusion and future work is described in segment IV.

II. Design of Antenna and Parametric Study

With the goal of designing the antenna and to observe as well as study the simulated results, the antenna has been designed by bearing the purpose to use in wireless applications in C-band (4 to 8 GHz). Subsequently, impedance bandwidth, AR, gain, radiation efficiency etc. are considered as the utmost significant parameters of the antenna to analyze and improve throughout the designing process. As the primary aim is to prove the workability of the antenna for wireless applications in C-band, the free space is taken as a simulation environment for throughout the simulation process. For designing of the antenna, Teflon is used as a substrate with thickness of 0.8 mm, dielectric permittivity (ϵ_r) 2.15, electric loss tangent 0.001 and thermal conductivity 0.3 W/M-K. Additionally, Copper having thickness 0.018 mm, thermal conductivity 401 W/M-K and electrical conductivity 5.96×10^7 S/m is chosen to design both the radiating patch and the ground plane. The total thickness of the antenna is 0.836 mm.

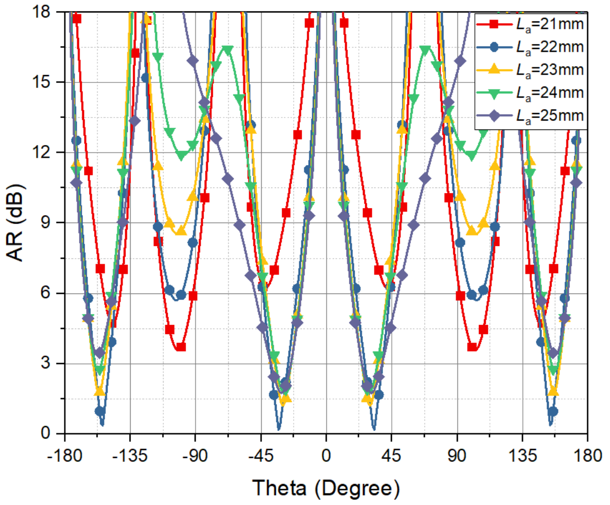


Fig. 4. AR for different values of L_a at phi=0°.

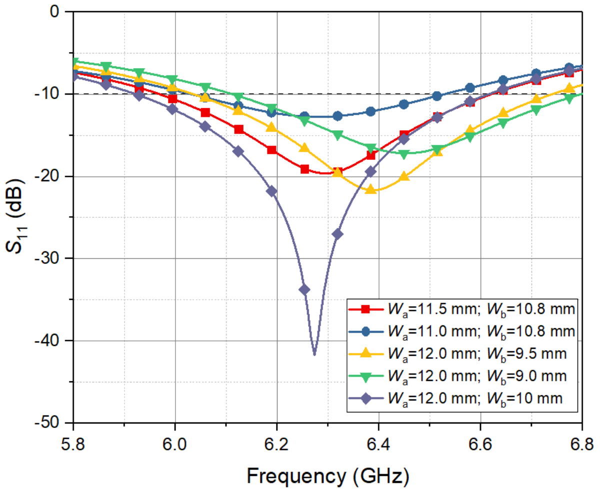


Fig. 5. S_{11} for different values of W_a and W_b.

Fig. 1 shows the top and bottom view of the proposed antenna. At the beginning, general and well-known formulas of the antenna are used to find the antenna's size parameter like length and width of the patch, ground, and substrate. An elleptical slot with unequal slot width is cut on the ground plane of the antenna. A single microstrip line that is on the top side of the antenna is used as feed line. The designed feed line is extended by quarter wavelength at the design frequency from the inner edge of the elliptical slot.With the intention of improvement in S_{11}, AR , gain and other parameters, the designed antenna was modified and scrutinized to perceive the best and optimistic result.

In design process, it has been noticed that changing the value of different parameter, there were tremendous change in characteristics of the antenna. Fig. 2 represents the variation of impedance against the variation of width of the microstrip feedline. The W_s = 2.4 mm was chosen to set the impedance nearer to the 50 ohm. The change of the frequency varying the numerical value of L_s has been displayed in Fig. 3. The value of L_s is 15 mm, has been selected to set the frequency range in C-band with a wide range of bandwidth comparing the other results. The minimum AR is needed to find the minimum XP radiation. From the Fig. 4, it is exhibited that the variation of AR at the resonance frequency

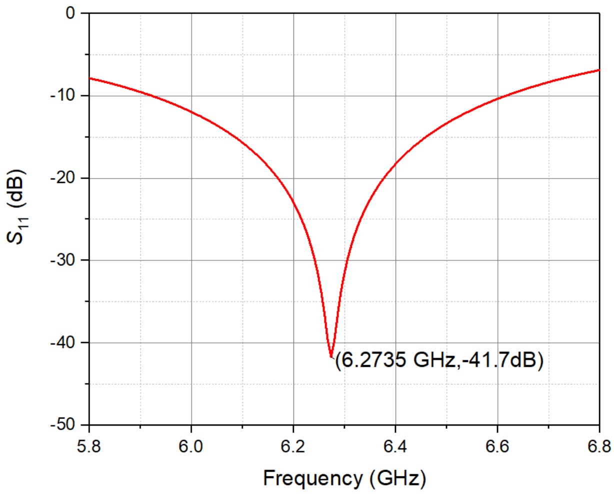


Fig. 6. Simulated S_{11} of the proposed CP antenna.

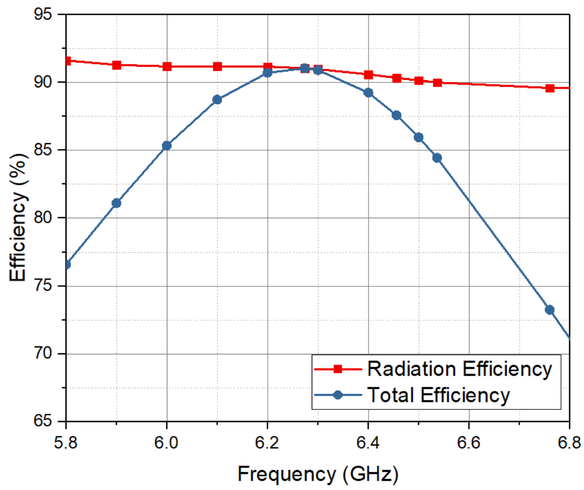


Fig. 7. Radiation and total efficiency of the proposed antenna.

TABLE I. NUMERICAL VALUE OF ANTENNA SIZE PARAMETERS

Parameter	Dimension (mm)		Parameter	Dimension (mm)
W	30		L_b	21.8
L	50		W_b	10.2
L_a	22		L_s	15
W_a	12		W_s	2.4

6.2735 GHz with the alternation of the L_a. Decreasing the value of L_a, the polarization of the antenna is going to CP from LP. The minimum AR of 0.37 dB has been achieved at L_a = 22 mm.

Fig. 5 displays the S-parameters with the variation of the parameters W_a and W_b. From this figure, it is observed that the maximum bandwidth of 690 MHz is accomplished for the value of W_a = 12 mm and W_b = 10.8 mm. In view of the above result, the numerical value of the parameters have been chosen so that the antenna's performances will exhibit best result in the practical field. Table I is populated with the final values of every parameters. After design and extensive simulation, the complete dimension of the antenna is 50 mm × 30 mm × 0.836 mm which is proposed in the paper.

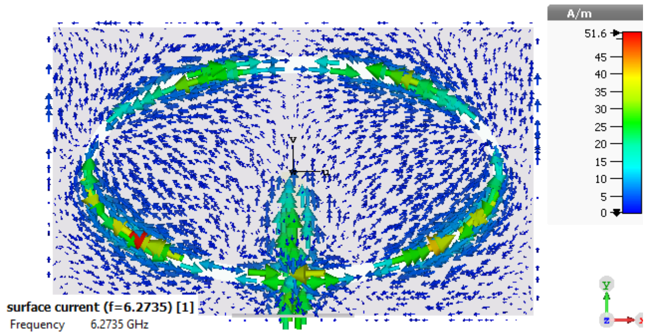


Fig. 8. Surface current distribution of the proposed antenna at the 6.2735 GHz frequency.

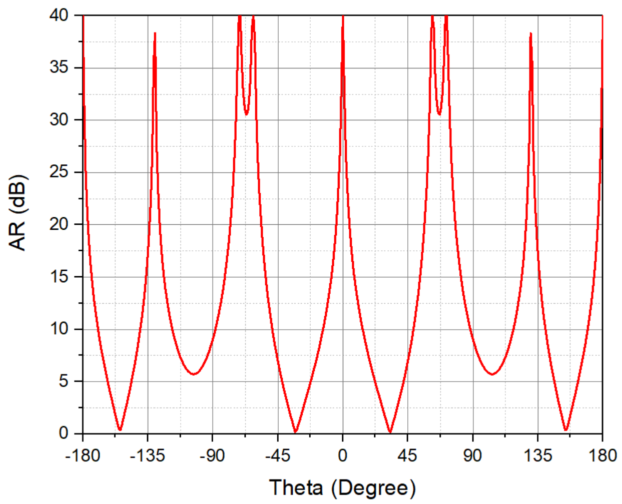


Fig. 9. AR performance of the proposed antenna at resonance frequency at phi = 0°.

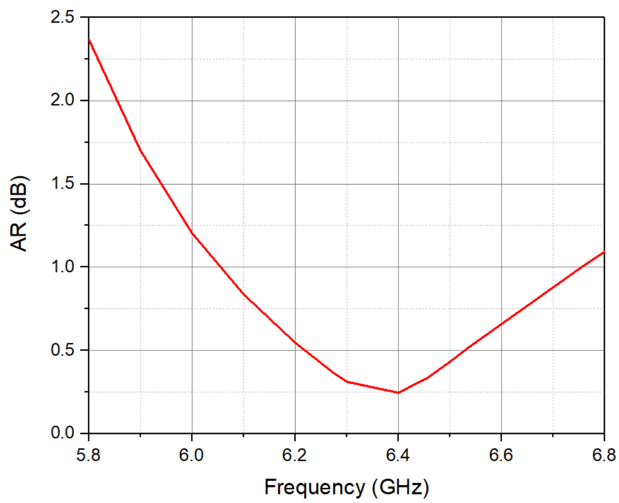


Fig. 10. AR vs frequency at phi = 0° and theta = 154°.

III. Simulation Results and Discussion on Performance

The designed antenna has been simulated using CST microwave studio to evaluate its performances. Comprehensive simulations have been performed for examining the antenna performances for wireless applications. The result of S_{11} parameter is shown in Fig. 6.

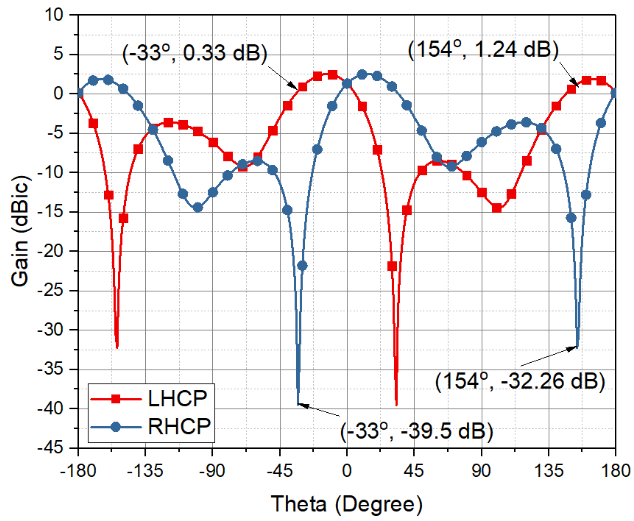


Fig. 11. CP radiation performance of the antenna at 6.2735 GHz at phi = 0°.

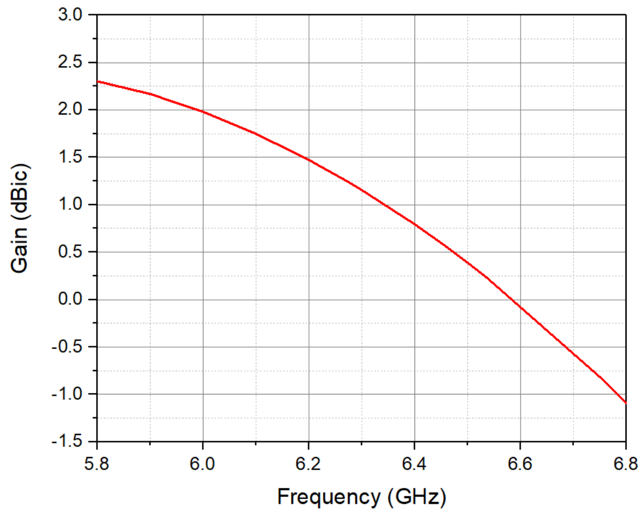


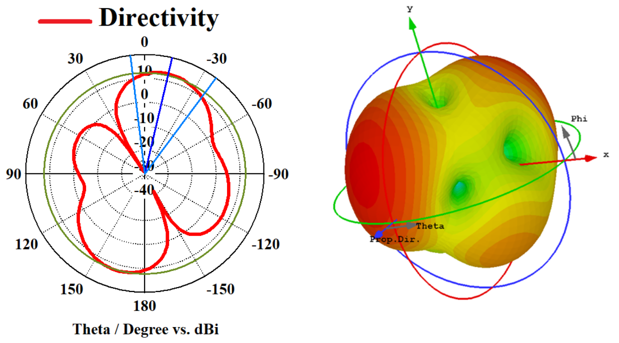
Fig. 12. Gain vs frequency at theta = 154° and phi = 0°.

S_{11} is less than −10 dB and minimum −41.7 dB has been achieved at the resonance frequency 6.2735 GHz .

The antenna's impedance bandwidth is 690 MHz; a quite outstanding result for any wireless satellite based application. Fig. 7 represents the radiation and total efficiency of the proposed antenna. The maximum radiation efficiency is 92% achieved at the resonance frequency 6.2735 GHz.

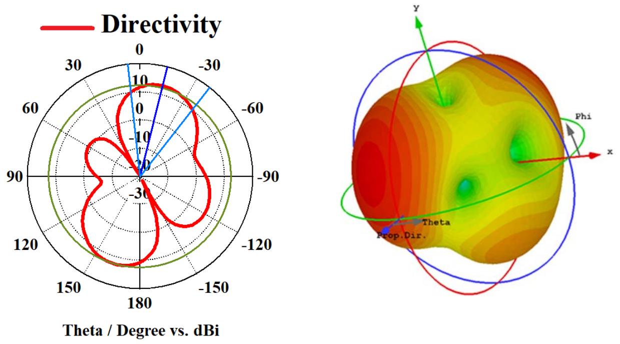
Fig. 8 illustrates the surface current of the proposed antenna at 6.2735 GHz. For CP, the horizontal and vertical E fields must be perpendicular to each other with equal magnitude. It is obvious from the Fig. 8 that the direction of the current for patch and ground are perpendicular and finally produce CP at specific value of phi and theta.

To find the region of CP, the evalution of AR has been done and displayed in Fig. 9. From the Fig. 9, it is noticed that the AR of the antenna at theta = 154° and phi = 0° is 0.37 dB which is less than standard value of AR (< 3 dB) for the CP antenna. The AR bandwidth is 690 MHz as shown in the Fig. 10. A noteworthy result of AR bandwidth for workability of the antenna in wide range of wireless practicle applications is achieved.



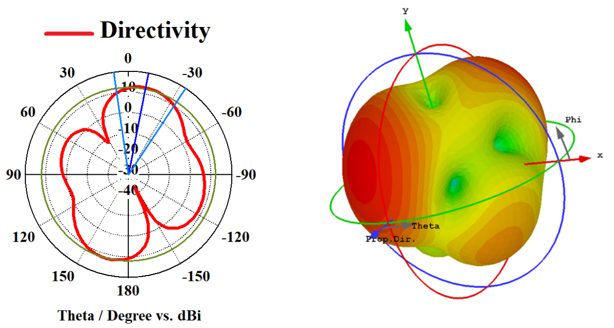
(a) (b)

Fig. 13. Far-field pattern (phi = 0°) at 6.2735 GHz. (a) Polar. (b) 3D.



(a) (b)

Fig. 14. Far-field pattern (phi = 0°) at 6.2 GHz. (a) Polar. (b) 3D.



(a) (b)

Fig. 15. Far-field pattern (phi = 0°) at 6.456 GHz. (a) Polar. (b) 3D.

Fig. 11 shows the simulated CP radiation performance of the antenna at phi = 0°. The gain of LHCP is found 1.24 dB and the gain for RHCP is −32.26 dB according to the figure. The outstanding difference between co-pol (LHCP) and cross-pol (RHCP) component is 33.50 that denotes that the polarization of the antenna is LHCP at Theta = 154°. Additionally at theta = -33° is also found maximum difference but gain at this theta is less than the theta = 154°.

The evaluation of gain of the antenna at different frequencies has done and the outcome is presented at Fig. 12.

The far-field characteristics of the antenna is also studied and the far-field result in polar as well as 3D for the resonance frequency of 6.2735 GHz is shown in Fig. 13. The result, shown in Fig. 13, describes outstanding far-field performance with the main lobe magnitude of 2.94 dBi and a small amount of side lobe along with the maximum directivity of 4.462 dBi.

Furthermore, Figs. 14 and 15 display the polar and 3D result of the far-field for the frequency 6.20 GHz and 6.4656 GHz, respectively. The radiation on both side of the antenna is common for a slot antenna, with a nearly constant directivity.

IV. Conclusion

A simple elliptical slot CP antenna has been described in this article. Good impedance matching and wider AR bandwidth are obtained in this antenna. Moreover, the antenna with a directivity of 2.94 dBi shows excellant CP radiation performance with a cross-polarization level better than 30 dB. These performances make the proposed antenna feasible to work in the arena of wireless communication like satellite based application. Working for better performance and fabrication as well as testing its feasibility for the practical application could be considered as future work.

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