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Excitation Amplitude/Phase Sensitivity in Circularly Polarized Hexagonal S-Band Antenna

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Abstract

A probe-fed circularly polarized hexagonal patch antenna with dual feed configuration is designed and presented for analyzing amplitude and phase sensitivity. The hexagonal patch antenna is excited with a fundamental frequency of 2.45 GHz through two feeds separated by an angle of 90˚ and 90˚ phase shift. The probe feed positions are optimized along the X- and the Y-direction of the patch antenna plane with and without simultaneous excitation. The sensitivity of circular polarization purity towards change in amplitude and phase of excitation signal is studied for a dual port hexagonal S-Band antenna.

Keywords—S-band antenna, probe feeding, circular polarization, dual feed, hexagonal patch antenna.

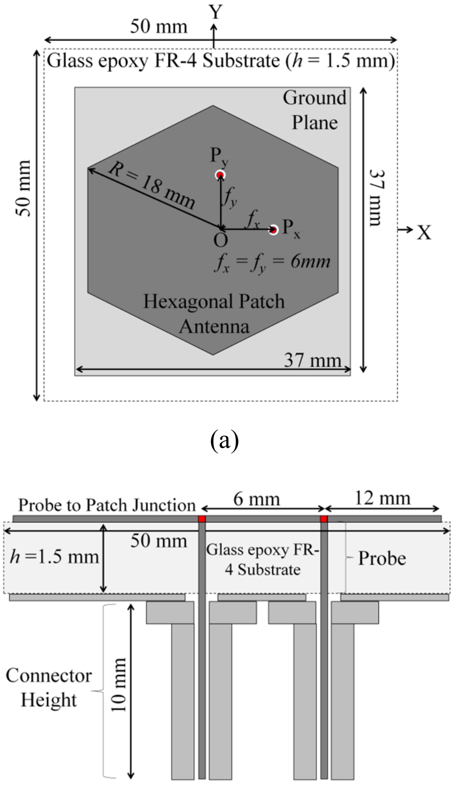
1. Introduction

Planar antennas with circular polarization are popular because of the feature of relative insensitivity to receiver and transmitter orientation [1]. A probe-fed patch antenna with circular polarization (CP) has been studied and designed by Chen et al. [2]. Chang et al. constructed an economic probe fed patch antenna that is capable of broadband CP radiation, which is suitable for wireless local area network (WLAN) and mobile satellite communication [3]. Ooi et al. introduced a dual band antenna which has an application in ISM bands (especially 2.45 GHz and 5.8 GHz) with circular polarization radiation [4]. Wu et al. presented an antenna with CP for mobile radio frequency identification (RFID) reader (2.45 GHz) and WLAN application with a gain of 6.32 dBi [5]. A perturbed hexagonal patch antenna has been described using LTCC technology, which has dual band characteristics (3.5/5.2/5.8 GHz bands) with circular polarization due to the stacked-patch and inserted slits [6]. The axial ratio bandwidth and S_{11} of the circularly polarized antenna was improved by 11.02 % and 2.45 % especially using probe strip and a substrate with good thickness when utilized for RFID applications [7]. To obtain circular polarization, it is necessary to achieve an axial ratio close to unity. In order to achieve axial ratio close to 0 dB, orthogonal E-vectors of equal amplitude but with 90˚ phase difference is required. One solution to achieve the circular polarization is dual but orthogonal feed technique. A technique was introduced by Ogurtsov et al. for enhancing circular polarization in patch antenna excited with two equal amplitude inputs separated by 90˚[8]. Axial ratio analysis is significant in order to understand the polarization characteristics of an antenna. Guraliuc et al. performed axial ratio analysis and achieved an axial ratio of 0.9 dB at 2.53 GHz for single feed truncated corner patch antenna. The 3-dB axial ratio bandwidth ranges from 2.479 to 2.58 GHz [9]. Wireless communication receiver also discriminates the sense of polarization i.e. left hand circular polarization (LHCP) and right hand circular polarization (RHCP) depending on the rotation of the wave. Zhang et al. achieves a controllable polarization for LHCP and RHCP for a 3-dB axial ratio Bandwidth of 2.726–2.739 and 4.486–4.501 GHz respectively [10]. It is quite interesting to perform axial ratio analysis to understand the polarization characteristics of the hexagonal patch antenna.

In this paper, a hexagonal patch antenna is demonstrated and analysed to study the excitation amplitude and phase sensitivity; and is compared with rectangular patch antennas those are widely explored [1, 11]. A hexagonal antenna with thin dielectric substrate is used for study and analysis. The paper demonstrate and explain how the axial ratio and sense of polarization is dependent on the excitation amplitude and phase. Finally, the observations based on the results of designed antenna are concluded in the last section of the paper.

2. Antenna Design

The designed hexagonal patch antenna with dual feed configuration is shown in Figure 1. The hexagonal patch is etched on a glass epoxy FR-4 substrate. The substrate with dimension 50 mm × 50 mm is sandwiched between the hexagonal patch with circumradius R =18 mm and the ground with dimension 37 mm × 37 mm. The two feeds P_x and P_y are optimized along the X-axis and along the Y-axis to achieve 50 Ω impedance at the desired resonating frequency, with a distance from origin f_x and f_y respectively. The side view of the designed antenna is shown in Figure 1(b).



(a)

(b)

Figure 1. Schematic of the designed antenna (a) Front view (b) Side view.

3. Parametric Study and Analysis

Different simulations on commercial available software (CST MWS) are performed to analyse and understand the effect of patch antenna geometry on axial ratio and sense of polarization. Three different but regular patch geometries i.e. circle (A1), square (A2) and hexagon (A3) operating at 2.4 GHz are chosen for the comparative analysis. The glass epoxy FR-4 substrate (ε_r = 4.3 and tan δ = 0.025) with height (h =1.5 mm) is sandwiched between the patch and the ground, in all antenna geometries. The substrate and the ground dimensions are same for all the geometries as indicated in Figure 1(a). In all simulations, standard subminiature (SMA) connector with pin radius of 0.62 mm and outer conductor with radius 2.57 mm and height 10 mm is used as reflected in Figure 1(b). While performing simulations, the radius (R) of the antennas geometries are varied in order to achieve circular polarization centered at 2.4 GHz. In order to have circular polarization in all antenna geometries orthogonal dual feed with 90˚ phase excited signals is used.

3.1 Antenna Geometry Analysis

Initially, for comparison of geometries A1, A2 and A3 the aspect ratio (W/L) is kept equal to 1, considering the W along the Y-axis and L along the X-axis. The dimensions of patch geometry for unity aspect ratio are 16.5 mm circumradius (R) for A1, R = 20 mm for A2 and 31.16 mm × 31.16 mm for A3. It is interesting to note that in all the three configurations, the optimum value of feed radial distance from the origin is same i.e. $f_x = f_y$ = 6 mm. The sense of polarization i.e. left hand circular polarization (LHCP) and right hand circular polarization (RHCP) is attained by adjusting the phase angle of excitation signal at the orthogonal ports P_x and P_y. When two orthogonal feed points P_x and P_y are fed with $1\angle 90^\circ$ and $1\angle 0^\circ$ respectively, RHCP is obtained while LHCP is obtained by feeding $1\angle 0^\circ$ and $1\angle 90^\circ$ to P_x and P_y respectively. But hexagonal planar antenna (A3) do not provide circular polarisation when W/L = 1 while A1 and A2 do provide circular polarization with W/L = 1.

With an objective to establish circular polarization at 2.4 GHz, antennas A1, A2 and A3 are compared, and AR ≅ 0 dB is observed as reflected in Figure 2. It is interesting to note that antenna A1 and A2 have the similar 3-dB bandwidth range for both LHCP and RHCP but different for antenna A3 as may be observed from Figure 2. This may be due to the aspect ratio (W/L) of regular hexagon which is 1.15, while 1 in case of A1 and A2. LHCP and RHCP are observed at different frequencies for same patch with a different of 200 MHz motivates for further analysis towards axial ratio of the hexagonal planar antenna. The optimum dimension for R are 16.5 mm, 20 mm and 18 mm for A1, A2 and A3 respectively. The 3-dB axial ratio bandwidth of antenna A2 and A3 are mostly same, i.e. axial ratio bandwidth > 1 GHz while for A1, axial ratio bandwidth < 1 GHz. It is also interesting to observe that in A1 and A2, the center frequency is same for both LHCP and RHCP but for A3, LHCP radiates at 2.5 GHz while RHCP radiates at 2.3 GHz.

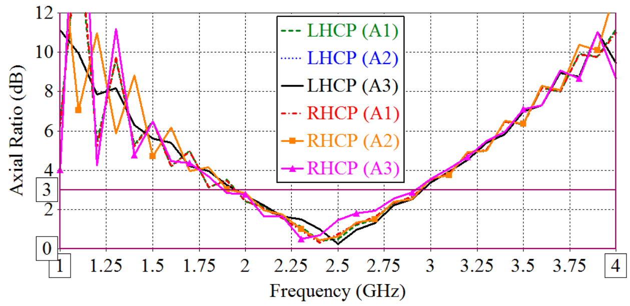


Figure 2. Simulated Axial Ratio (in dB) (AR) of different antenna (A1 - A3) configurations.

3.2 Excitation Phase Sensitivity Analysis

The excitation phase sensitivity analysis is significant because in practice, the phase difference between the two orthogonal ports, i.e. P_x and P_y may not be equal to 90˚ due to feeder or cable or connector produced phase errors. To analyze the effect of phase imbalance on axial ratio the phase of one of the excitation signal is varied while keeping the phase at other feed constant.

To analyze the effect of phase imbalance on RHCP, the phase of excitation signal at the feed P_x of the proposed antenna A3 is varied with the fixed amplitude of 1, while P_y is excited with $1\angle 0^\circ$ at 2.4 GHz. The effect of the phase imbalance can be observed in Figure 3. The axial ratio at 2.4 GHz is below 3 dB, when the phase is between the 65˚ and 105˚.The phase sensitivity analysis suggests that antenna configuration A2 has a fixed AR response for both LHCP and RHCP while antenna configuration A3 has a minimum value of AR at 88˚ and 98˚ for RHCP and LHCP respectively.

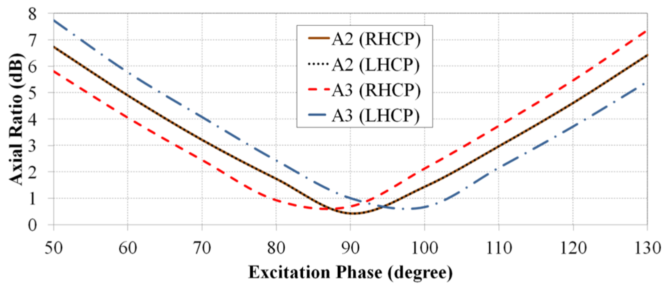
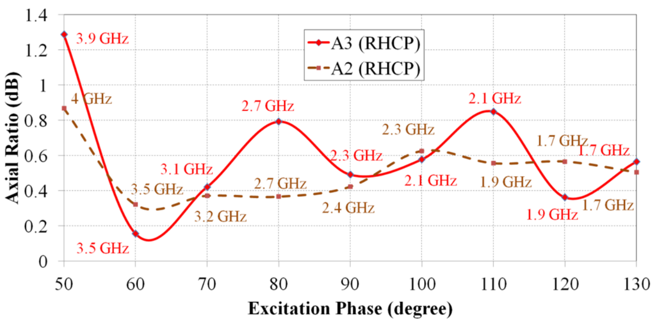
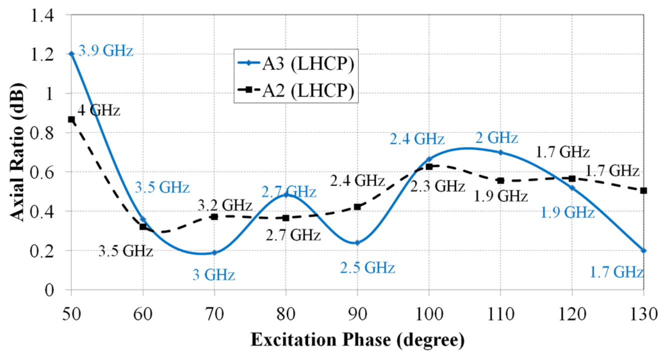


Figure 3. Simulated Axial Ratio (in dB) (AR) of antenna A2 and A3 configurations with different values of excitation phase for RHCP and LHCP at 2.4 GHz.



(a)



(b)

Figure 4. Simulated minimum Axial Ratio (in dB) (AR) of antenna A3 configurations with different excitation phase (a) RHCP (b) LHCP.

In order to track the minimum value of axial ratio of A2 and A3, at different values of the excitation phase for RHCP and LHCP respectively, different simulations are performed and results are indicated in Figure 4. Minimum axial ratio is observed with shift in operating frequency.

The effect of change in phase on RHCP and LHCP is analyzed by varying the phase of the excitation signal at one feed P_y of the proposed antenna A3 with the fixed amplitude of 1, while the other orthogonal feed is excited with $1\angle 0^\circ$ at 2.4 GHz. The excitation phase sensitivity analysis suggests that the proposed antenna A3, the frequency at circular polarization shift as the phase of the excitation signal varies. The circular polarization frequency is dependent on the phase of the excitation signal. This feature definitely makes the proposed antenna A3 suitable for frequency reconfigurable application at the two sense of polarization i.e. LHCP and RHCP for 2.4 GHz.

3.2 Excitation Amplitude Sensitivity Analysis

In practice, amplitude between the two orthogonal ports, i.e. P_x and P_y may not be equal to 1 due to feeder or cable or connector losses. To analyze the effect of amplitude imbalance on axial ratio the amplitude of one of the excitation signal is varied while keeping the amplitude at other orthogonal feed constant. For instance, to analyze the effect of amplitude imbalance on RHCP, the amplitude of excitation signal at feed P_y of the proposed antenna A3 is varied with the phase of 0˚, when P_x is excited with $1\angle 90^\circ$ at 2.4 GHz. The effect of the amplitude offset can be visualized in Figure 5.

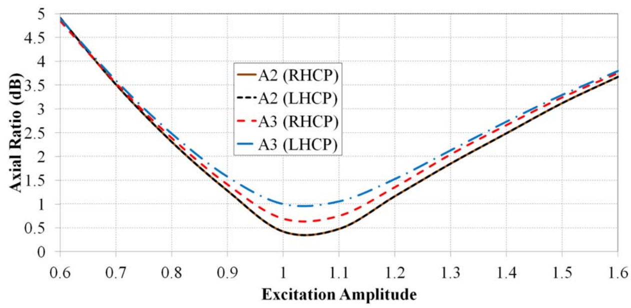
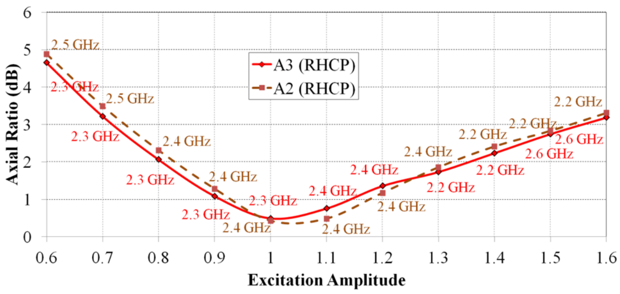


Figure 5. Simulated AR of antenna A2 and A3 configurations with different excitation amplitude for RHCP and LHCP at 2.4 GHz.

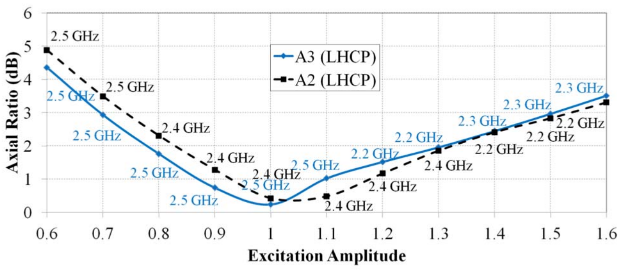
The axial ratio at 2.4 GHz is below 3dB, when the excitation amplitude is between the 0.75 and 1.45. As observed earlier in Figure 2 that the axial ratio of the proposed hexagon will have a higher axial ratio at 2.4 GHz. Figure 5 shows minimum axial ratio or circular polarization sensitivity towards amplitude variation. The minimum axial ratio is achieved when amplitudes of the excitation signals at both the ports are unity or balanced.

To analyze the effect of amplitude imbalance on LHCP, the amplitude of excitation signal at the feed P_x of the proposed antenna A3 is varied with the phase of 0˚, when P_y is excited with $1\angle 90^\circ$ at 2.4 GHz. Previously it is observed that when the sense of polarization of the proposed hexagon is RHCP and LHCP, the minimum value of axial ratio is at 2.3 GHz and 2.5 GHz respectively, as shown in Figure 2. The Left hand circular polarization sensitivity towards amplitude variation is plotted in Figure 6.

The excitation amplitude analysis of different antenna configuration suggests that the axial ratio of proposed antenna A3 is very much sensitive to amplitude imbalance. To maintain the circular polarization in case of hexagonal patch antenna the amplitude difference should not be more than the 0.25.



(a)



(b)

Figure 6. Simulated minimum Axial Ratio (in dB) (AR) of antenna A2 and A3 configurations with different excitation amplitude for (a) RHCP (b) LHCP.

4. Conclusion

This paper presents a hexagonal patch antenna which radiates circular polarization when excited at two orthogonal ports with equal amplitude, and 90˚ phase shifted inputs. Due to the hexagonal shape of the antenna it becomes easier to identify the 50 Ω feed position along the two orthogonal axis of the designed antenna plane to achieve circular polarization. When compared to square or circular counter parts, Axial ratio bandwidth ~ 1 GHz is observed same, but possibility of achieved lower axial ratio is observed in hexagonal patch antenna. The excitation phase and amplitude sensitivity analysis suggest that the axial ratio of hexagonal patch antenna is quite sensitive to amplitude and phase imbalance of excitation signal as compared to the axial ratio of a rectangular patch antenna.

5. Acknowledgements

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6. References

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