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Research Article

Bandwidth Enhancement of Circularly Polarized Hexagonal Microstrip Patch Antenna using L-Cut in Patch

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Abstract

Hexagonal shaped microstrip patch antenna is presented with single coaxial feed, along with L-cut in hexagonal patch to improve the impedance bandwidth and circular polarization bandwidth. The circular polarization of two antennas is obtained, for simple hexagonal patch axial ratio (AR) is 1.31% and 2.25% axial ratio for hexagonal patch with L-cut in patch antenna. The impedance bandwidth obtained for simple patch is 1.85% and 8.5% for L-cut in hexagonal patch. The feed position is optimized for the best impedance matching to a 50 Ω coaxial feed line. Radiation efficiency and average gain of antenna are evaluated.

Keywords: *Microstrip antenna, hexagonal microstrip antenna, single coaxial feed, circularly polarized microstrip antenna.*

1. Introduction

Circular polarization (CP) is beneficial over linear polarization (LP) because there is no need of alignment of the electric field vector at the transmitting and the receiving places. So circular polarization is widely used in wireless communication systems and global navigation satellite system and military applications. The circular polarization (CP) antenna does not require alignment of electric field vector at the receiving and transmitting end. Single feed CP antenna reduces the complexity of feeding circuit, weight and size of antenna. CP antennas are also useful as dual orthogonal feed power dividers but they are not suitable for present sensors because of large size (K P Ray, D.M. Suple &N. Kant , 2009),(P.C Sharma, Kuldip C. Gupta,1983).

An antenna with regular geometrical shaped patch radiates linear polarized waves when feed with a single feed point. A single patch antenna can also radiate circular polarization and elliptical polarization depending on the amplitudes and phase of the excited modes. To radiate circular polarized wave, two perpendicular modes must have equal amplitude and must be ±90 degrees out of phase. The sign of the phase determines the direction of rotation i.e. right hand circularly polarized (RHCP) or left hand circularly polarized (LHCP) (Ray & Suple, 2009),(Ray, Suple, kant, 2010). This is achieved by 45° from the x-axis coaxial feeding. The performance of antenna can be improved by introducing a parasitic element. The parasitic elements can placed in horizontal plane and in vertical plane. When the parasitic element is placed in vertical plane over the feed driven patch, it reduces the size and becomes suitable for wireless communication system and when placed in horizontal plane with driven element, it increases the size of antenna (Agrawal & Bailey, 1977).

So far circular polarization has been generated using various shapes i.e. circular, triangular and square. The hexagonal geometry of antenna of simple patch with circular polarization has been studied comparing with the L-cut in hexagonal patch antenna structure.

2. Design of circular microstrip antenna (CMSA)

For designing the hexagonal patch antenna, designing of circular patch antenna must be considered because these are closely related to each other. The resonant frequency of circular microstrip antenna can be determined using the following equation:

$$f_r = \frac{\chi_{mn} C}{2\pi a\sqrt{\varepsilon_r}} \quad (1)$$

Where f_r= resonant frequency, Xmn=1.8411 for the dominant mode TM_{11}, c=velocity of light in free space, ε_r=relative permittivity of the substrate.

Effective radius of circular microstrip antenna is given by:

$$a_e = a\left\{1 - \frac{2h}{\pi a \varepsilon_r}\left(\ln\frac{\pi a}{2h} + 1.7726\right)\right\}^{1/2} \quad (2)$$

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Where a= the actual radius of the circular patch antenna as shown in Figure 1, h= height of the substrate and $\varepsilon_{r=}$ relative permittivity of the substrate.

3. Hexagonal microstrip antenna (HMSA) design

Hexagonal microstrip patch antenna is one of the various shapes capable for obtaining circular polarization(Ramesh & Bhartia,1980).The designing of hexagonal microstrip antenna can be done by using variation of static energy below hexagonal circular patch(Ray, Suple, kant, 2010).The relationship between the equivalent areas of circular and hexagonal patches in given by (Ramesh & Bhartia,1980).

$$\pi a_e^2 = \frac{3\sqrt{3}}{2} s^2 \qquad (3)$$

Where a_e is effective radius of circular patch and S is side of hexagonal patch. The top view of hexagonal microstrip patch is shown in figure 2.

4. Antenna configuration

1. Simple hexagonal microstrip patch

This antenna is designed on FR4 substrate with dielectric constant ε_r = 4.3.The substrate size is 50 mm x 50 mm and thickness h=1.53mm. The side length of hexagonal patch antenna is calculated using (3) to 11mm at the central frequency f_o =3.5GHz as shown in Fig. 2. Circular polarization is achieved by optimizing the feed location from the center of patch to an angle of 45° from x-axis. HFSS software is used to optimize the feed position of antenna. These parameters are common for all both the structures in this paper.

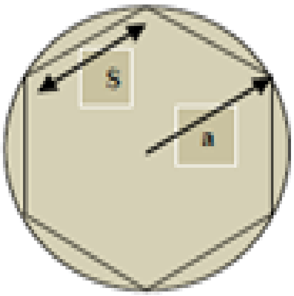


Fig.1 Circular Microstrip Patch

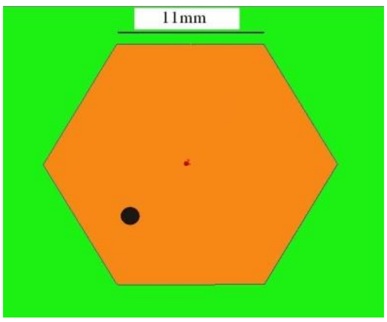


Fig. 2 Top view of hexagonal patch

2. Hexagonal patch antenna with L-cut in patch

An L –slot is designed on the hexagonal patch of size 6.2mm and 2.4mm.Top view of this structure is shown in the figure 3. This antenna structure of L- slot is simulated by optimizing the feed position and length of L-cut in patch. The center frequency thus obtained from this antenna is shifted towards higher frequency 4 GHz and bandwidth is also increased.

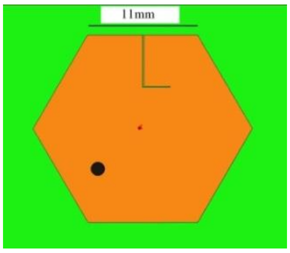


Fig. 3 Top view of simulated Hexagonal patch with L-cut

5. Simulated results and discussion

1. Impedance bandwidth

The two antennas (Simple hexagonal patch and hexagonal patch with L cut) are designed and simulated using Ansoft HFSS. First designed the simple hexagonal patch at central frequency f_o = 3.47GHz and the feed location is optimized at d=2.96mm from the center of patch and along the diagonal. Impedance bandwidth of 70 MHz from 3.45 GHz to 3.52 GHz is obtained at VSWR 2:1 with 1.85 % bandwidth as shown in Figure 4.

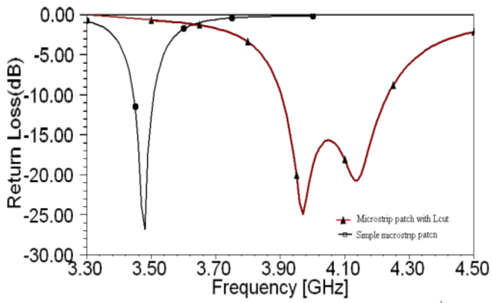


Fig. 4 Simulated Return Loss (dB) of simple patch an L-cut hexagonal patch antenna

In the second design, an L-cut is made in patch and we optimized its size and feed location. The optimum feed location is obtained at d=5.52mm from the center of patch and along the diagonal and side length of L-cut is obtained 6.2 mm and 2.4 mm. The measured impedance bandwidth is 340.50MHz from 3.9029 GHz to 4.2434 GHz which is about to 8.5% of the corresponding central frequency of 4GHz. This bandwidth of L-cut antenna is 6.65 % as compared to simple hexagonal patch antenna bandwidth. The simulated results of both antennas are tabulated in Table 1.

Table1 Resonant frequencies, impedance bandwidths and simulated gains of the two antennas

S No	Types of patch	Feed point (mm)	Impedance bandwidth (MHz)	Axial bandwidth (MHz)	Avg Gain (dB)	Eff. η %	f_0 GHz
1	Simple	2.96	64.4	45.80	6.0	94	3.47
2	Patch with L cut	5.52	340	90	6.5	83	4

It can be observed from the Fig 4 that as the impedance bandwidth increases, central frequency shifts towards higher frequency for L-cut against the simple patch antenna.

2. Axial ratio

Axial ratio is used to characterize the purity of circular polarization. If the axial ratio of an antenna is less than 3 dB over any frequency band, then this antenna is said to be circularly polarized in that frequency band. Both antennas are simulated for axial ratio. Axial ratio bandwidth is calculated at 3 dB and simulated axial ratios of both antennas are shown in Figure 5. Axial ratio bandwidth achieved for the simple hexagonal patch is 45.8 MHz from frequency 3.44GHz to 3.49GHz at 3 dB axial ratio. This axial bandwidth is 1.85 % of the center frequency 3.47 GHz. For second antenna structure, the simulated axial ratio bandwidth is achieved 90MHz from frequency 3.9541GHz to 4.0435GHz and this corresponds to 2.25% axial bandwidth at 3dB with center frequency 4GHz.It is observed that axial ratio bandwidth increases in case of L-cut patch antenna in comparison to simple hexagonal patch antenna.

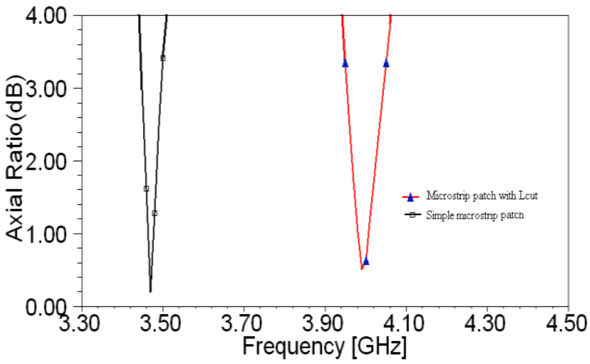


Fig. 5 Simulated axial ratio for simple hexagonal Patch, L-cut hexagonal patch

3. Average gain and radiation efficiency

Simulated average gain of both antennas are shown in the Fig.6. The average gain of the simple hexagonal patch is equal to 6db and for L-cut patch antenna it is 6.50 db at center frequency. The average gain of L-cut patch antenna increases as compared to hexagonal patch antenna.

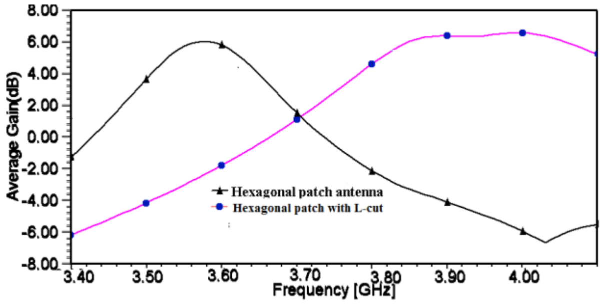


Fig. 6 Simulated average gain (dB) for simple hexagonal Patch, L-cut hexagonal patch

The radiation efficiency of the both antenna has also been calculated. Fig. 7 shows comparison of the radiation efficiencies of both antennas. Radiation efficiency is obtained 94% for simple hexagonal patch, 83% for L-cut patch antenna.

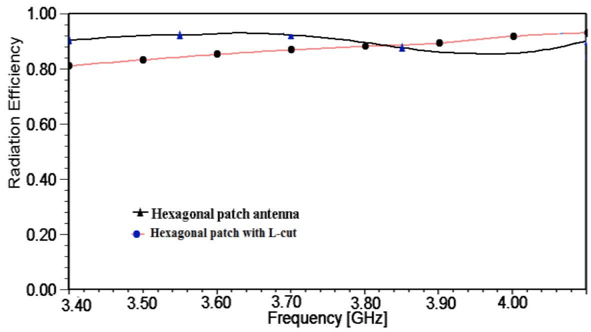
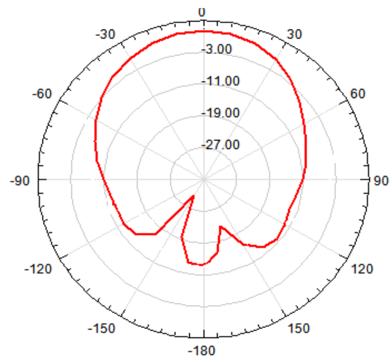


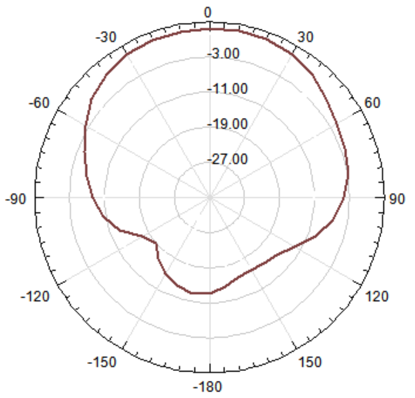
Fig. 7 Simulated Response of radiations efficiency (η) for simple hexagonal Patch, L-cut hexagonal patch

4. Radiation patterns

These antennas are simulated in E and H plane for radiation patterns at center frequency. The radiation patterns of simple microstrip hexagonal patch is simulated at 3.47 GHz as shown in Fig. 8 and Fig. 9.

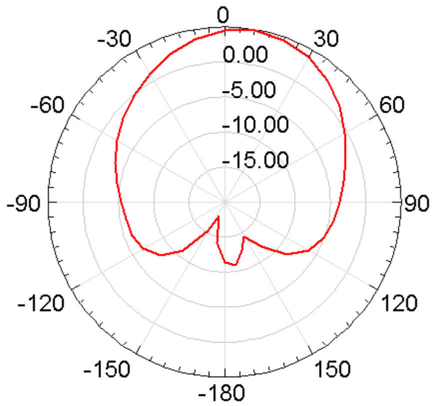


(a)

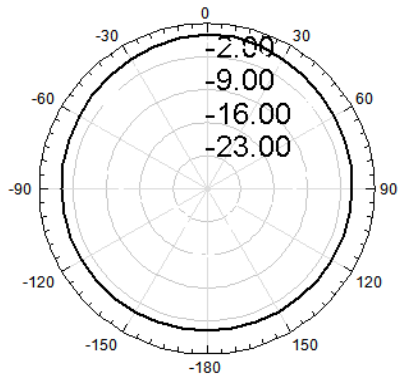


(b)

Fig. 8 Simulated radiation paterrn of simple patch (a) E-Plane (b) H-Plane at f=3.47GHz



(a)



(b)

Fig. 9 Simulated radiation pattern of L-cut hexagonal patch antenna (a) E-Plane (b) H-Plane at f=4GHz

These figures show the simulated radiation pattern of L-cut patch antenna. The red color show the radiation pattern in the E-plane and black color shows the radiation pattern in H-plane. It is observed from the radiation pattern that the back side of both E-plane and H-plane reduces in L-cut patch antenna as compared to simple hexagonal patch antenna.

Conclusions

Both simple hexagonal patch and L-cut patch antenna have been designed and simulated with respect to bandwidth, average gain, efficiency and axial ratio. The bandwidth of L-cut patch is more in comparison to simple hexagonal patch antenna bandwidth. The average gain achieved for L-cut hexagonal patch antenna is more than simple hexagonal patch antenna and similarly the radiation efficiency of L-cut patch antenna is greater than the radiation efficiency of the simple hexagonal patch. The radiation pattern of L-cut patch antenna in E and H plane are also found better than the simple hexagonal patch antenna. It is observed that the hexagonal patch antenna with L-cut design is another circular polarization antenna which offers better performance in term of impedance bandwidth, axial ratio and average gain. The design of these antennas is very simple and it is easier to fabricate with MIC/MMIC. These antennas find application in wireless communication.

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