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CIRCULARLY POLARIZED TRUNCATED PENTAGONAL SHAPED MICROSTRIP PATCH ANTENNA

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Abstract**—** In this paper a low profile pentagonal microstrip patch antenna has been proposed, we have seen the response of truncated pentagonal patch antenna designed at resonant frequency 2.42 GHz. The proposed antenna inhibiting of a single microstrip patch like low gain, thin substrate thickness, light weight and much small bandwidth, make it more versatile. This type of antenna is aggressive miniaturized to meet requirements of the wireless communication system.

Index Terms**—** Microstrip patch antenna, pentagonal, linear and circular polarization (CP)

1. INTRODUCTION

This printed patch antenna is low profile antenna, contented to planar and non-planar surfaces, simple and inexpensive to manufacture from present day printed technology. It is also usually inexpensive to manufacture and design. For improved antenna function, a wide dielectric substrate having a low dielectric constant is advantageous since this provides better capability, superior bandwidth and better radiation. Still, such a proposed design leads to a bigger antenna size. In designing a compact patch antenna, the materials having higher value of dielectric constant must be used which are less dexterous and results in narrow bandwidth. Hence conciliation must be reached between antenna dimensions and antenna performance [1-4].

The design and recreation of circularly polarized patch antenna, which can be implemented by properly making a small sized sector from a side of the equilateral-pentagon, patch [5]. The pentagonal-shaped microstrip patch antenna can be designed with only one probe feed to get circular polarization and it can be used for many wireless applications at different frequencies [6]. This article explains firstly Antenna analysis and design in section 2 and finally, it simulates the designed antenna which gives 6.8336 dB gain at 2.42 GHz with good circular polarization in section 3.

2. ANTENNA ANALYSIS

Microstrip antennas are commonly used at frequencies from 1 to 100 GHz and at frequencies below ultra high frequency, UHF microstrip patch become exceptionally large. The radiating patch of antenna can be designed in various shapes according to the desired characteristics like H-shape micro strip antenna [8] and spring shape micro strip antenna [7]. In order to simplify the analysis and performance prediction, the patch is generally square, rectangular, circular, triangular and elliptical or some other common shape.

Pentagonal microstrip patch gives better performance than the rectangular patch antenna. Geometry of a pentagonal patch is shown in Figure 1.It supports both linear and circular polarization. The pentagonal patch antenna gives circular polarization with only one feed where as rectangular patch antenna requires multiple feeds to get circular polarization [9]. The pentagonal patch antenna can also use multiple feeds and this type of antenna with multiple feeds can also give multiband operations [10]

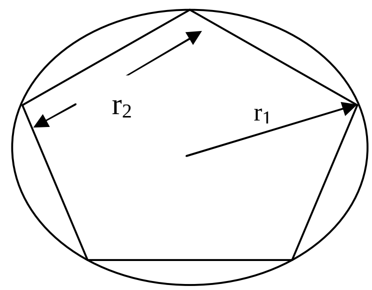

Figure 1 Geometry of a pentagonal patch

Circular polarization is theoretically possible from a microstrip antenna excited by a single feed if two spatially orthogonal modes are excited in phase quadrature. This can be achieved in a pentagonal patch as shown in Figure 3.

2.1. ANTENNA DESIGN

The circularly polarized antenna which can be easily implemented by properly slice a section (*L*) from a side of the equilateral-pentagon patch in which the fundamental resonant mode of the equilateral - pentagon microstrip antenna and it is split into two near-degenerate orthogonal modes with equal amplitudes and a 90' phase difference [11-12].

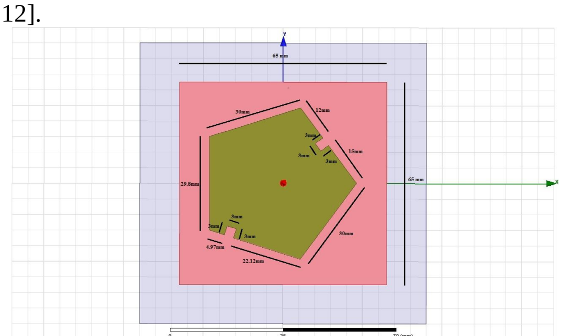

Figure 2 Design of a truncated pentagonal patch

The designed antenna which is operating at 2.42 GHz with circular polarization has many advantages compared to the other microstrip patch antennas. This can be shown in figure 2.

2.2. DESIGN PARAMETERS

The designed pentagonal microstrip patch antenna is a wideband small antenna with a thickness (*h*) of 62 mil and loss tangent of 0.0014. The Substrate i.e.; considered for microstrip antenna is RT-Duroid with dielectric constant $\varepsilon_r = 2.2$.This pentagonal patch design with a feed point at (2.2,-10) as in figure 2, gives 6.8336 dB gain at 2.42 GHz with good circular polarization. The pentagonal antenna size calculations were made considering the invariance of the electrostatic energy below the pentagonal and circular patches, keeping their areas remain constant [3]. The relationship between the circles (r_1) to the side arm of the regular pentagon (r_2) is given in equation 1(Fig.1).

$$r_2^2 = \frac{\pi r_1^2}{2.37} \qquad (1)$$

Side arm of the pentagon (r_2) = 1.175 r_1

In the derivation of the expression (1), the pentagonal patch is assumed to be a resonant cavity with perfectly conducting side walls. Because a circular disc is the limiting case of the polygon with large number of sides, in this case number of sides are 5. The resonant frequency of the dominant as well as for the higher order modes can be calculated from the formula given below:

$$f_{np} = \frac{X'_{np}\, c}{2\pi r_1 \sqrt{\varepsilon_r}} \qquad (2)$$

Where $J_n(x)$ represents the zeros of the derivative of the Bessel function of the order *n*, as is true for TE mode circular waveguides, however for the lowest order modes;

$$X'_{np} = 1.84118$$

The length of each side of the pentagonal antenna is calculated by using equation (1) & (2). For coaxial feeds, the location of the feed point is usually selected to provide a good impedance match.

2.3. DESIGN SPECIFICATIONS

The proposed pentagonal patch antenna has been designed using following specifications:

Substrate material = RT-Duroid
Feeding technique = Coaxial feed
Operating frequency range = 2.0-3.0 GHz
Dielectric substrate (ε_r) = 2.2
Velocity of light = $3*10^8$ m/s
Loss tangent = 0.0014
Operating frequency (*f*) = 2.42 GHz
Conductivity = $5.8 * 10^7$ S/m (copper)
Height of substrate (*h*) = 62 mil

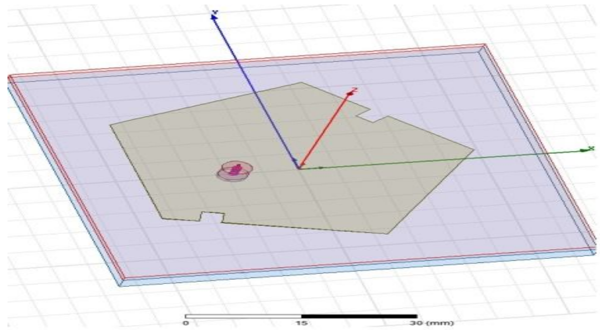

Figure 3 Top view of pentagonal patch

On the basis of analyzing the *ante*nna, this paper adopts the resonant frequency of 2.42 GHz, coaxial feeding point and high-permittivity substrate to design the pentagonal patch antenna as in figure 2.

3. SIMULATION RESULTS OF ANTENNA

The following results are obtained from the ANSOFT HFSS, V.13 simulation tool; these results are incorporating the antenna parameters as the designed pentagon shaped microstrip patch antenna gives the reflection coefficient as shown in the figure 4. i.e., S11 (dB) is -15.2331 dB which is minimum at resonant frequency of 2.42 GHz. The radiation pattern is depicted from the figure 5. The designed antenna is capable of generating circular polarization (CP) with the axial ratio of 2.8367 dB as in figure 8. And the antenna designed gives CP axial ratio <3 dB and bandwidth of 150 MHz Also it gives 6.8336 dB gain at 2.42 GHz with good circular polarization.

3.1. REFLECTION COEFFICIENT (S11)

At first the feed position is varied and its effect on the input impedance, S_{11} and V.S.W.R. are measured. The coaxial cable impedance in general is 50 Ω. Here a feed location point is to be found out on the conducting patch where patch impedance is 50 Ω. This feed point gives maximum radiation because of proper matching.

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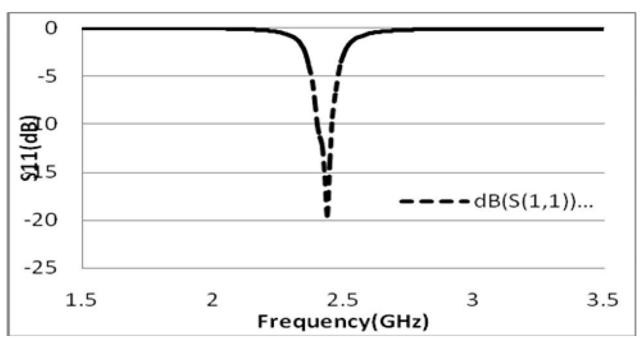

Figure 4 Return loss of proposed antenna

3.2. RADIATION PATTERN

The radiation pattern near the resonant band frequencies are shown in Figure 8. With an increase in frequency, the radiation pattern varies and the cross polar level increases significantly to the extent that the radiation becomes maximum along θ =30° at 2.42 GHz. At a higher frequency, the parasitic patches are resonant, and therefore experience a large phase delay with respect to the fed patch; hence, the beam maxima shifts away from broadside. The radiation pattern of the antenna shows that it is Omni-directional as well as circularly polarized with small levels of cross polarization as shown in Figure 5.

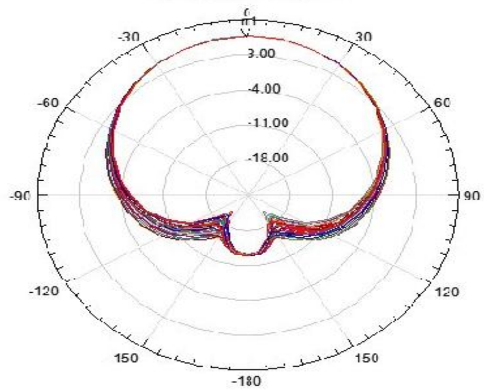

Figure 5 Radiation pattern of pentagonal patch with $\Phi = 0^0$, 90^0 Total Directivity is 6.8514 dB at $\theta = 0^0$

3.3 IMPEDANCE CURVE

The input impedance is defined as “the impedance presented by an antenna at its terminals” or “the ratio of the voltage current at a pair of terminals” or “the ratio of the appropriate components of the electric to magnetic fields at a point”.

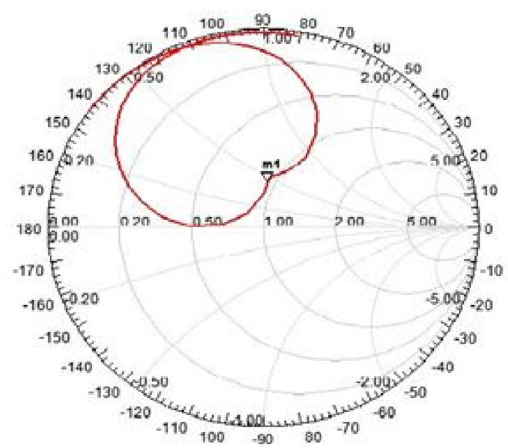

Figure 6 Simulation Result of pentagonal patch Input Impedance Loci using Smith Chart

3.3. VSWR

The simulated value of VSWR is 1.94891 at 2.42 GHz, and corresponding values of VSWR with frequency is plotted is Figure 7.

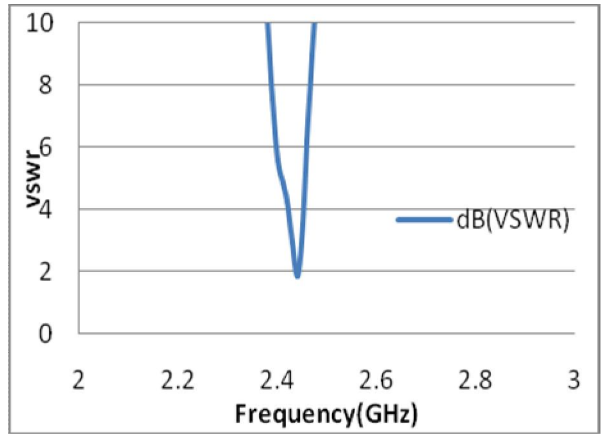

Figure 7 VSWR of pentagonal patch antenna

3.4. AXIAL RATIO

Axial ratio with respect to frequency is shown in Figure 8, and found that axial ratio at the resonant frequency (2.42 GHz) is around 2.8367 dB.

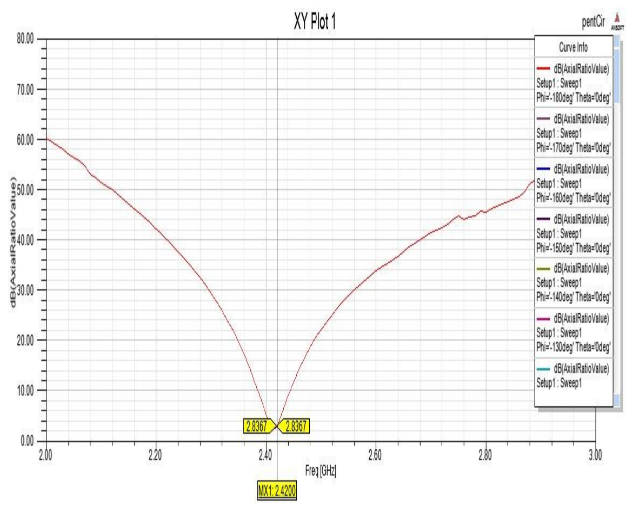

Figure 8 Axial ratio plot for pentagonal patch antenna

3.5. TOTAL GAIN

The gain for the optimized antenna is 6.8336 dB at $\phi = 0^0$

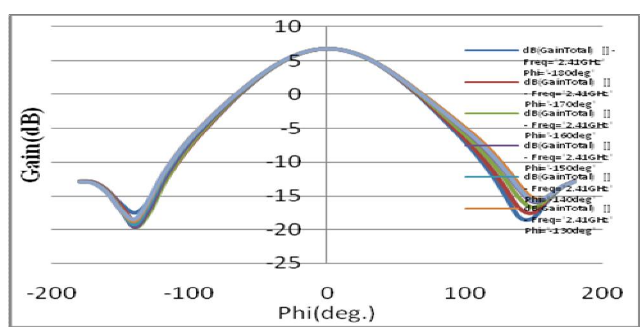

Figure 9 Total gain plot for pentagonal patch antenna

4. CONCLUSION

The truncated antenna is designed to have a good return loss and radiation pattern. The corresponding return loss obtained from simulation is -15.233 dB and VSWR is 1.94891 dB while the resulted directivity of antenna is 6.8514 dB. The value of impedance is passing through 1 on both the smith chart; it shows the perfect matching of probe impedance and patch impedance. It is also shown that the geometry with triangular slot has an influence towards the performance of the antenna characteristics

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