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Circular Slot Rectangular Patch Microstrip Antenna for Dual Band Application

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Abstract: Compact microstrip patch antenna with circular slot is proposed for dual band application. The proposed design offers wide bandwidth and dual band operation useful for WLAN and X band application. This antenna is designed by adopting a rectangular patch on FR-4 epoxy substrate with dielectric constant (ε_r) is 4.4. Antenna is simulated using electromagnetic solver HFSS. The antenna has small size of $21.1 \times 32 \times 1.6$ mm^3. The proposed antenna have return loss bandwidth of around 1.5 GHz (4.28 GHz – 5.84 GHz) i.e. 31% at lower band and 6 GHz (7.15 GHz – 13.21 GHz) i.e. 60% at higher band. The gain of antenna is 4.27 dB at resonant frequency. Various antenna characteristics like VSWR, Directivity, Impedance, Radiation pattern is also given in the paper.

Keywords: Fire Redundant-4 (FR-4), Wireless Local Area Network (WLAN), HFSS

I. INTRODUCTION

Antenna is a metallic device for radiating or receiving radio waves. Today a microstrip patch antenna is widely used in wireless communication applications. It is invented in the period of 1970. Microstrip antennas consist of metallic patch on grounded substrate. It is widely used because of their excellent features such as low cost, light weight, small size, easy to fabricate and also very versatile in the form of resonant frequency, radiation pattern, polarization and impedance. To design microstrip antenna a various methods or techniques are available in market. This antenna is firstly design on software for their results. If antenna gives required results then it will be ready to fabricate. This can be achieved by various software like Ansoft HFSS, IE3D, ADS, CST HP, GEMS and so on. The simulation of antenna is taken by using Ansoft High Frequency Structured Simulator (HFSS) software.

In this paper, a compact circularly polarized rectangular patch with circular slot antenna is proposed. Circularly polarized antennas have an advantage in reducing the loss caused due to polarization misalignment between signals and receiving antennas. A well-known method of generating circular polarization is by creating different shapes of radiating elements with a single feed, such as a rectangular patch with truncated corners. In this proposed antenna microstrip line method are used for feeding to become a universal design. This proposed antenna design on single layer, single feed, and dual band frequency of antenna. The proposed antenna designed on FR-4 substrate, is compact in size $21.1 \times 32 \times 1.6$ mm^2. This antenna is operated at 5.5 GHz.

This antenna was designed for various application such lower band is used for wireless local area network (WLAN) and higher band is used for television broadcasting, radar, satellite communication etc. Details of designed antenna with simulation carried out through the software package HFSS and the experimental results are presented.

II. DESIGN OF ANTENNA

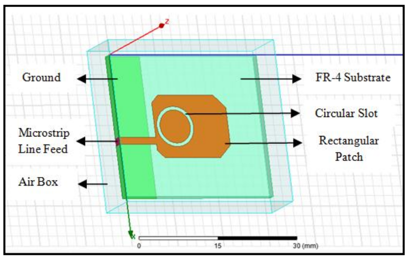

Fig.1: Design of proposed Antenna

A circular slot rectangular patch microstrip antenna is shown in Fig.1. Rectangular patch considered as radiating patch with length L and width W. The length and width are calculated by transmission line model. Circular slot is designed by introducing two circular ring cuts from the patch. This method is similar to slot loading technique. The radiuses r_1 and r_2 of circles are estimated by circular patch antennas formula. In our design, the circular slot design with four slits (corner cutting) is proposed. By adjusting the length of slits, the impedance and bandwidths can be improved. Rectangular patch can achieved as transmission lines, because these antenna have physical shape derived from microstrip transmission line. The transmission line is one of the most intuitively appealing models for analysis the rectangular microstrip patch antenna.

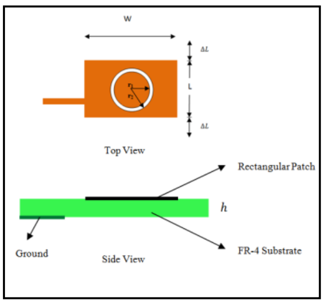

Fig.2: Geometry of rectangular patch

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For efficient radiation the width (W) of rectangular patch is calculated by,

$$W = \frac{c}{2f_0}\sqrt{\frac{2}{\varepsilon_r + 1}}$$

Where, f_o = Operating frequency
c = Velocity of light in free-space
ε_r = Dielectric constant (i.e. 4.4 for FR-4)

Fringing makes the microstrip line wider and longer electrically compared to its actual physical dimensions. Effective dielectric constant is calculated by,

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-1/2}$$

Where, ε_{reff} = Effective dielectric constant
h = Height of dielectric substrate

$$\Delta L = 0.412 \times h \times \frac{\varepsilon_{reff} + 0.3}{\varepsilon_{reff} - 0.258} \times \frac{W/h + 0.264}{W/h + 0.8}$$

Fringing effects leads to lengthening of L and widening of W. The dimensions of the patch along its length have now been extended on each end by a distance ΔL, which is a function of ε_{reff} and W/h (Width to Height Ratio). It is calculated by,

For a given resonant frequency the effective length is calculated by,

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{reff}}}$$

Now the actual length (L) of the patch is calculated by,
$L = L_{eff} - 2\Delta L$

The geometry of rectangular patch of microstrip antenna where length (L) = 12.45 mm on x-axis and width (W) = 16 mm on y- axis. The dielectric FR-4 substrate having dimension 28.1 mm in length and 32 mm in width placed between ground planes and radiating patch. The thickness of the substrate is 1.6 mm, relative dielectric constant (ε_r) is 4.4 and loss tangent (tanδ) is 0.02. By increasing the thickness of substrate, efficiency and bandwidth can be increase. Ground plane is partial which is made up of a rectangular part with a length of 28.1 mm and width of 7.4 mm. For achieving higher bandwidth circular slot is added on the rectangular patch. The radius of outer circle is r_1= 3.3 mm and inner circle radius is r_2= 4 mm having center is (14.225, 12.5, 0) mm.

The radiating patch is fed by 50Ω coplanar waveguide transmission line. The width of the feed line is 1.2 mm fixed in such a way that it should achieve the characteristic impedance of 50Ω. The microstrip line feed is also a conducting strip, usually of much smaller width compared to the patch. The microstrip line feed is easy to fabricate, simple to match by controlling the inset position and rather simple to model. The bandwidth of the antenna without corner cut is very small. To broaden its bandwidth, two corners cut of radiating patch. For two corners cutting, results are not so good therefore to get better result again two corner cuts of the radiating patch.

Table 1: Parameters

S. N.	Parameters	Value
1	Substrate Dimension($l \times w \times h$)	(28.1×32×1.6)mm
2	Patch Dimension (L × W)	(12.45 × 16) mm
3	Ground Dimension	(28.1 × 7.4) mm
4	Radius of outer circle (r_1)	4 mm
5	Radius of inner circle (r_2)	3.3 mm
6	Microstrip Dimension	(1.2 × 8) mm
7	Dielectric Constant (ε_r)	4.4
8	Loss tangent (tan δ)	0.02
9	Feeding Impedance	50Ω

III. RESULTS AND DISCUSSION

Fig.3 shows the S_{11} reflection coefficient graph for the proposed antenna. From the graph it can be seen that for the lower band reflection coefficient -19.13 dB at 4.84 GHz resonating frequency with a bandwidth (BW) is approximately 1.5 GHz (4.28 GHz – 5.84 GHz). It exhibits a bandwidth 31% of center frequency. For the higher band reflection coefficient is -30.65 dB at 12.17 GHz with bandwidth is approximately 6 GHz (7.15 GHz – 13.21 GHz). It exhibits a bandwidth 60% of center frequency.

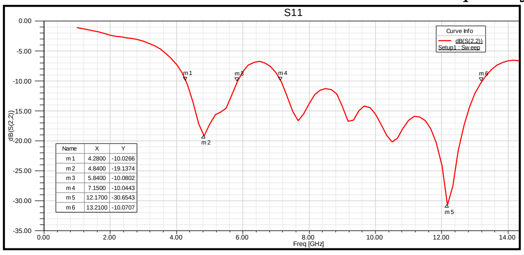

Fig.3: S11 Reflection Coefficient

Fig.4 shows graph between Voltage Standing Wave Ratio (VSWR) Vs frequency in GHz. VSWR is a function of the reflection coefficient, which describes the power reflected from the antenna. VSWR is the ratio of the peak amplitude of a standing wave to the minimum amplitude of a standing wave. VSWR between 1 and 2 is considered very well for an antenna. Here it is 1.24 at 4.84 GHz and 1.06 at 12.17 GHz.

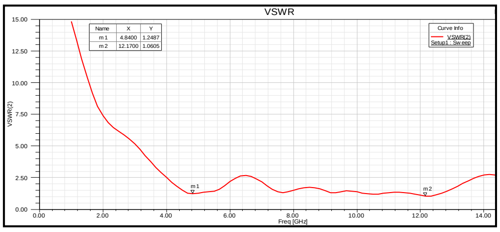

Fig.4: VSWR of Proposed Antenna

Fig.5 shows input impedance graph of proposed antenna. This graph shows real and imaginary value at particular frequency. At 4.84 GHz real value is 40.54 and at 12.17 it is 47.95 which are nearer to 50. For good result, real value closer to 50 because our resistance is 50 ohm.

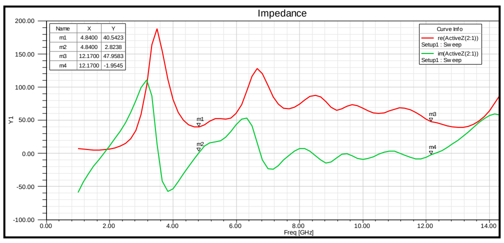

Fig.5: Impedance Graph

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Fig.6 shows Smith chart of proposed antenna. Here real value at 4.84 GHz frequency is 0.80 and at 12.17 GHz it is 0.95 which is closer to 1 for best result and imaginary value is 0.0495 and 0.0406 respectively which is closer to 0. It shows real and imaginary values are good matching between the load and source.

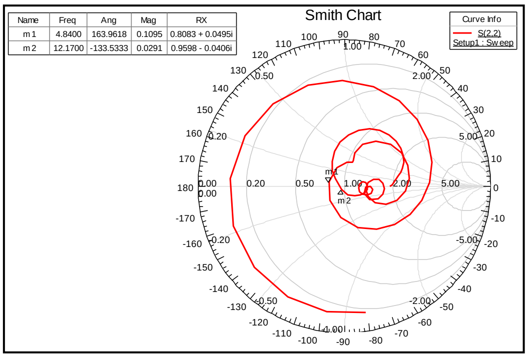

Fig.6: Smith Chart

The directivity of an antenna defined as "the ratio of the radiation intensity in a given direction from the antenna to the radiation intensity averaged over all directions. The average radiation intensity is equal to the total power radiated by the antenna divided by 4π. If the direction is not specified, the direction of maximum radiation intensity is implied." Fig.7 shows the directivity of proposed antenna is 4.83 dB.

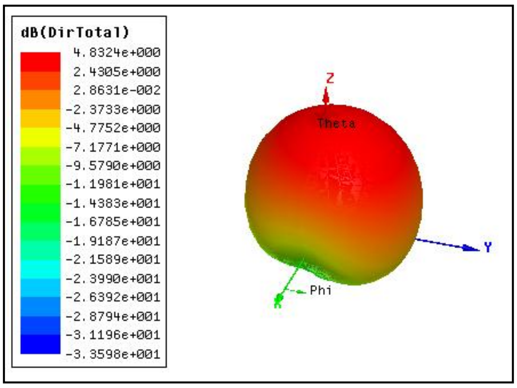

Fig.7: Directivity of Antenna

Fig.8 shows the gain of proposed antenna is 4.27 dB. Gain of an antenna is defined as "the ratio of the intensity, in a given direction, to the radiation intensity that would be obtained if the power accepted by the antenna were radiated isotropically. The radiation intensity corresponding to the isotropically radiated power is equal to the power accepted (input) by the antenna divided by 4π.

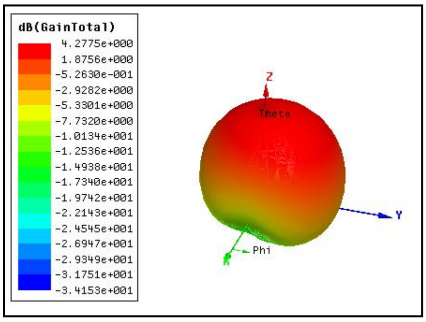

Fig.8: Gain of Proposed Antenna

Fig.9 shows the stimulated radiation pattern of proposed antenna at 0 degree and 90 degree.

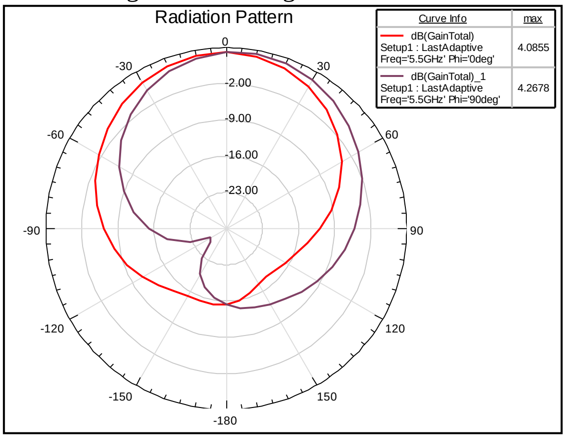

Fig.9: Radiation Pattern

IV. CONCLUSION

In this project, design of circular slot rectangular patch microstrip antenna for dual band application is proposed. The proposed antenna is suitable for most of the wireless communication application. Lower band (4.28 – 5.84 GHz) having bandwidth percentage is 31% is used for WLAN and higher band (7.15 – 13.21 GHz) having bandwidth percentage is 60% is used for television broadcasting, radar, satellite communication etc. The main advantage of this proposed antenna is good gain with circular polarization. Maximum gain of antenna is 4.27 dB at resonant frequency. Also VSWR is less than 2 and it is best for wireless communication.

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