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Design and Analysis of Circularly Polarized Micro-strip Patch Antenna using HFSS

Lavi Agarwal
Assistant Professor
MIT, Moradabad, UP, INDIA

Prateek Rastogi
M.Tech. Student
S.I.T.E. Meerut, UP, INDIA

ABSTRACT
In this paper, design and analysis of circularly polarised micro-strip patch antenna is presented. The use of circularly polarised antenna is an attractive solution to achieve polarization matching between the transmitting and receiving antenna. It is compact design of a square of 35.8 mm side with opposite corner by removing 11 mm each side on Rogers TMM4 substrate with dielectric constant of 4.5, thickness of 1.524mm and feed by a coaxial feed technique. The Proposed antenna is operated between 2.4-2.7 GHz with below 2 db VSWR. This antenna is having axial ratio below 3 db over the band of 2.55-2.69 GHz. The Parameter of this antenna such as radiation pattern, return loss, VSWR and axial ratio is simulated using HFSS software.

Keywords
Circular Polarization, Axial Ratio, Radiation Pattern.

1. INTRODUCTION
Nowadays micro-strip patch antenna is widely used for various applications. There is a serious limitation of this antenna is narrow bandwidth. For radar communications and navigation systems, Circular Polarization is particularly useful because the rotation orientation of the transmitter and the receiver antenna are unimportant in relation to the received signal strength [1]. The circularly polarized wave reverses its sense of polarization from right hand to left hand circular polarization and vice versa to produce predominantly orthogonal polarization [1]. These types of circularly polarized antennas can typically be single or dual feed, although the presence of second feed requires an external polarizer capable of producing the phase offset required [2]. Micro-strip antenna is having a serious limitation of surface wave propagation and the presence of surface wave reduce the antenna efficiency and gain, limit the bandwidth, increase end-fire radiation, increase cross polarization radiation and limit the applicable frequency range [3]. Thicker substrate increases the bandwidth of antenna [4]. Truncating patch corners or cutting a diagonal slot in the patch are some of the conventional methods for achieving circular polarization of single feed square micro-strip antennas [5]. The radiation efficiency of the antenna decreases due to the power carried away by the surface waves. Since a cavity backed antenna is designed in this paper. The purpose of this paper is to optimize axial ratio below 3 db over the operating band.

2. DESIGN CONSIDERATION
In this paper, the performance of circularly polarized micro-strip antenna has been investigated.

The proposed antenna is designed on Rogers TMM4 substrate having the dielectric constant of 4.5, thickness is 1.524mm and 0.002 dielectric loss tangents. Figure (1) shows the basic shape of this antenna.

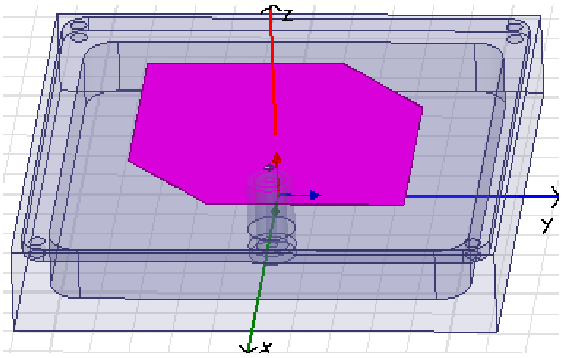

Fig. 1: Model of the designed antenna

This antenna consists of a square patch of 35.8mm on substrate with perturbation of 11 mm of two opposite sides. In this configuration we are using cavity enclosed micro-strip patch antenna. Cavity enclosed micro-strip patch antennas have gained considerable interest from antenna designers due to their miniature configuration, isolation from surroundings, reduced backward radiation, and suppression of surface waves.

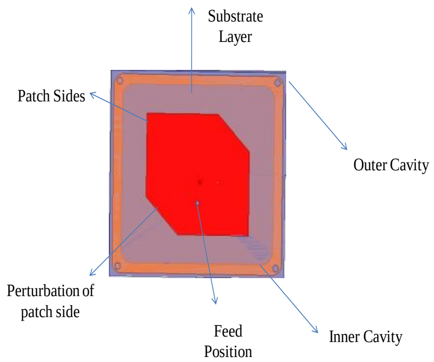

Fig. 2: Front View of circularly Polarized Micro-strip Antenna

With the help of cavity we are reducing the size of the antenna without greatly affecting the antenna performance.

Table 1 Dimensions of the Cavity Backed Patch Antenna

Part of The Antenna	Dimension(mm)
Outer Cavity size	61/61/8.524 (L/W/H)
Inner Cavity Size	53/53/8.524 (L/W/H)
Substrate Height	1.524
Patch Size	35.8
Feed Point	8.5 with respect to x

The above table describe all the dimension of this antenna.

3. RESULT & DISCUSSION

After the designing procedure, antenna is simulating using HFSS software. Since some important curve such as real or imaginary part of impedance variation with frequency, return loss, VSWR (voltage standing wave ratio), radiation pattern, gain, axial ratio. According to our requirement antenna should be operated in S band and its axial ratio should be below 3 db over the band i.e. 2.56 GHz to 2.57 GHz. VSWR is defined as a measurement of the mismatch between the load ant the transmission line. Return loss (S11) represent how much power is reflected from the antenna. Larger S11 means that most of the part of transmitted energy will be lost because the reflected energy is almost equal to the incident energy, now still need to tune the antenna, and it is may be due to mismatch in the transmission line. Antenna should not have S11 above -10 db.

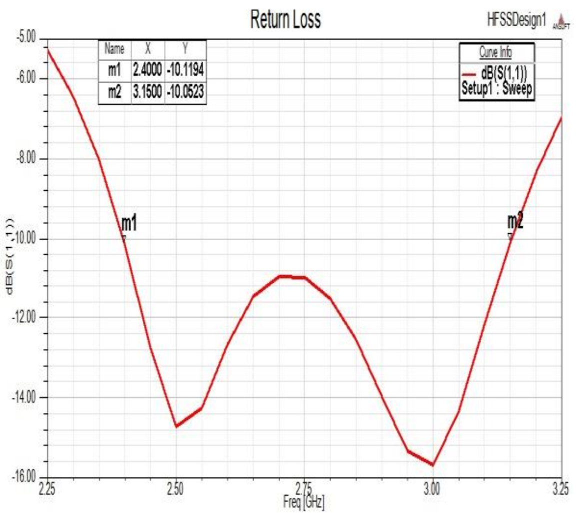

Fig. 3: Variation of return loss with frequency of circularly polarized micro-strip antenna

The graph of return loss with frequency is shown in below figure3. Frequencies at which minimum return loss occur for this antenna is given in table 2. As observe from table 2 and curve in fig. 3 return loss is below -10 db over the band.

Voltage Standing Wave Ratio is defined as a measurement of the mismatch between the load and the transmission line.

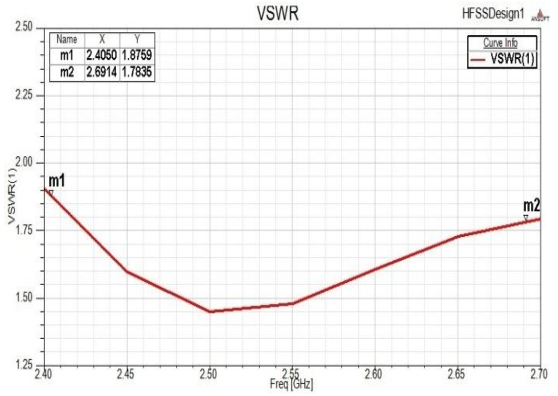

Fig. 4: Variation of VSWR with frequency of circularly polarized micro-strip antenna

Variation of VSWR with respect to frequency is shown in figure 3. From the plot it can be seen that VSWR<2 at about 2.4 GHz to 2.7 GHz. It is clear from the graph that when antenna is operating for S band, it is in decreasing nature for this band and comes closer to the ideal value of 1.The VSWR is found to have the minimum value of 1.47 at 2.5 GHz.

The axial ratio is a very important parameter that helps to quantify the polarization of an antenna. For antennas that have perfect circular polarization, the axial ratio is 1 (or 0 dB), because you have electric field components of the same magnitude, if it is an antenna with elliptical polarization, the axial ratio is greater than 1.

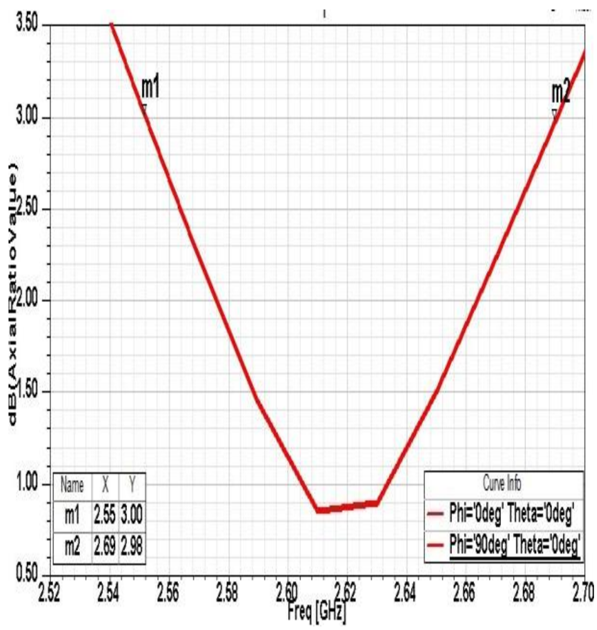

Fig. 5: Variation of Axial Ratio with frequency of circularly polarized micro-strip antenna

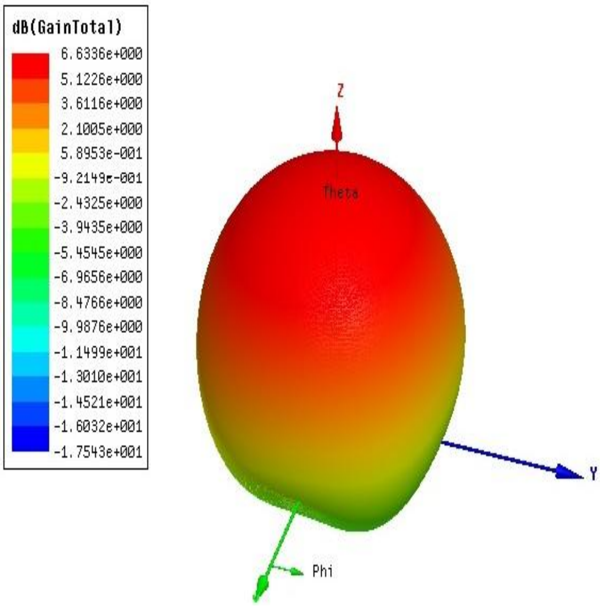

Fig. 6: 3D Radiation Pattern of Circular Polarized micro-strip antenna

This graph shows the antenna axial ratio versus frequency with 3 dB axial ratio bandwidth is 5 %. Above plot is showing the radiation pattern of circularly polarised radiating element.

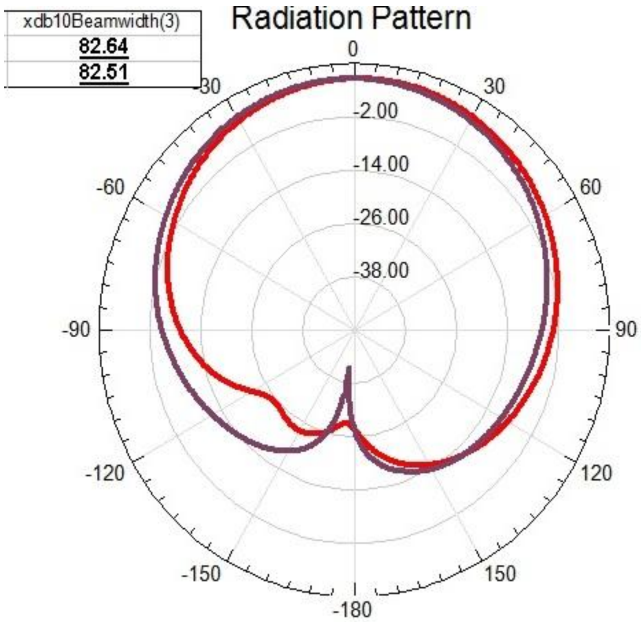

Fig. 7: 2D Radiation Pattern of circularly polarized micro-strip antenna

The above graph is showing the beam width of radiated energy that can define in which direction it can radiate maximum.

Table 2 Result analysis using HFSS

Analysis Parameter of Antenna	Frequency Range	Simulated result
Return Loss	2.4GHz-3.15GHz	< -10 dB
VSWR	2.4GHz-2.69GHz	< 2
Axial Ratio	2.55GHz-2.69GHz	< 3dB
Gain	2.6GHz	6.6dB
Beam width	2.6GHz	82.6dB

4. CONCLUSION

The goal of this paper is to design and analyse a circularly polarised cavity backed radiating element using HFSS. Basically an oversized patch is replacing by a single fed patch with cavity. This antenna has been designed to operate in a very popular frequency range where a great number of wireless communication application exist. In this paper, its circular polarization is improving by optimizing its parameter. The circularly polarised cavity backed radiating element is designed in which this is excited by coaxial feeding. The various parameters like input impedance, VSWR, return loss and radiation pattern are calculated using HFSS software. The measured results were found to be in good agreement that is acceptable for our application. The circularly polarised cavity backed patch antenna exhibits 5% axial ratio bandwidth and return loss below -10 db over the band i.e. 2.5 GHz to 2.7 GHz. After discussing the various simulated results of this radiating element, it can be used for an application where circular polarization is needed. For future modification, a parasitic patch can be coupled to this radiating element since its axial ratio bandwidth will be improved. Simulation can be done for more than one element or array arrangement with this cavity backed antenna. Several observations were made during the analysis of this antenna.

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