International Journal of Computer Engineering in Research Trends
Multidisciplinary, Open Access, Peer-Reviewed and fully refereed
Research Paper | Volume-6, Issue-3, 2019 Regular Edition | ISSN: 2349-7084

Quad-Band Circularly Polarized Patch Antenna for UWB/5G Applications

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Available online at: http://www.ijcert.org

Received: 23/03./2019, Revised: 27/03/2019, Accepted: 03/04/2019, Published: 11/03/2019

Abstract: A quad-band circularly polarised (CP) patch antenna for 7.1/7.6/7.9/8.6 GHz for UWB/5G applications are proposed in this paper. By designing the patch antenna with an inverted U-shaped radiator, I-shaped and L-shaped strips which are all rotated by 45° at the horizontal axis. The measurement of -37.51 dB of return loss for 8.6 GHz frequency was obtained.

A microstrip line feed technique was used for feeding which is one of the contacting schemes used in the feeding methods. A conducting strip is connected directly to the edge of the microstrip patch. It provides a simple planar structure since the conducting strip is smaller in size when compared to the patch. The substrate FR_4 epoxy has high electrical insulation, good mechanical strength, better wear, and corrosion resistance. The measured 3 dB AR information is 5.63% (6.9-7.3 GHz), 5.26% (7.4-7.8 GHz), 5.0% (7.8-8.2 GHz) and 3.50% (8.4-8.7 GHz) severally. This antenna can be used in UWB/5G applications which offer high-speed data transmission.

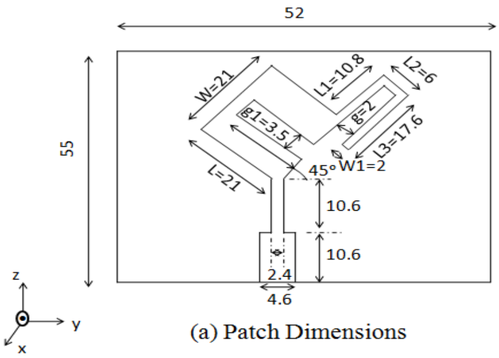
Keywords- Microstrip Antenna, Circularly Polarized (CP) Antenna, Inverted Strips, Microstrip Line Feeding, Multi-Band Antenna, UWB (Ultra Wide Band).

1. Introduction

An antenna acts as an intermediate between radio waves propagating through free space and electric currents moving in metal conductors, used with the transmitter or receiver. The antennas are of two types, one is an omnidirectional antenna, and the other one is a high gain directional antenna. Once the radio waves are transmitted, they propagate as electromagnetic waves in the free space. After the electromagnetic waves arrived at the receiving antenna, a voltage is induced into the antenna. The radio frequency voltage which was received at the receiver side was given to the antenna for the amplification process [1]. In the late 1970s, microstrip antenna technology development began rapidly. In the early 1980's design and modelling microstrip antenna elements are well established, and workers turned their attention to improving antenna performance features like bandwidth. One of the applications of the new technology of integrated phased array systems used micro strip antennas. A micro strip antenna consists of a dielectric substrate separated conducting patch on a ground plane [2]. In designing a micro strip antenna, its radiation pattern, input impedance, length, width and gain characteristics are considered, and also various parameters consideration are discussed in this paper. In this work, a quad-band CP antenna for UWB and 5G rate applications are conferred. Such that 7.1/7.6/7.9/8.6 GHz frequency bands are achieved by a patch antenna composed of an inverted U-shaped radiator including features of I-shaped and L-shaped strips, all revolved by 45° around the horizontal axis.

2. Design Methodology

This section describes the look method of the planned antenna. First, a CP patch antenna similar to that in [3] is intended on a FR4_epoxy substrate with a thickness of 1.52 mm, a material constant of 4.4 and a dissipation factor of 0.018. The substrate FR_4 epoxy has high electrical insulation, good mechanical strength, better wear, and corrosion resistance.



(a) Patch Dimensions

Figure 1 – Antenna Design

3. Feeding Technique

In our paper, we have used a microstrip line feeding technique to give input to an antenna. A conducting strip is connected directly to the edge of the microstrip patch [5]. It provides a simple planar structure since the conducting strip is smaller in size when compared to the patch. And so it can be etched on the same substrate.

To match the impedance of the feed line with the patch, the purpose of the inset cut in the patch is used. So that, no additional matching element is required [3]. It is also cheap and easily available. We have used copper material for patch, a microstrip line and the ground due highly reactive and much harder.

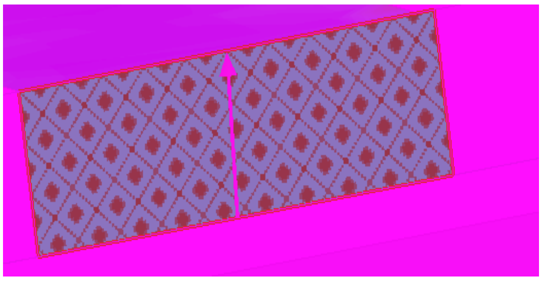


Figure 2 – Port Excitation

Tabulation for Patch Dimensions:

S. No	Description	Dimension (mm)
1.	**L**	**21**
2.	**W**	**21**
3.	**L_1**	**10.8**
4.	**L_2**	**6**
5.	**L_3**	**17.6**
6.	**W_1**	**2**
7.	**g_1**	**3.5**
8.	**G**	**2**

4. Design in Ansoft HFSS

The following figure shows the outline of the quad-band CP patch antenna using Software Ansoft HFSS. After designing the ground, substrate, and patch, then we should assign materials for the respective substances. Create a port for feeding the antenna. Assign boundary of E-Field for patch and ground. Assign limit of radiation only for the radiation box. Assign excitation for the port along with the primary line [5]. Now, set the solution setup and add frequency sweep. Then, validate and analyze all. After that, we can create various Modal

Solution Data Report, Field Report and Far-Fields Report.

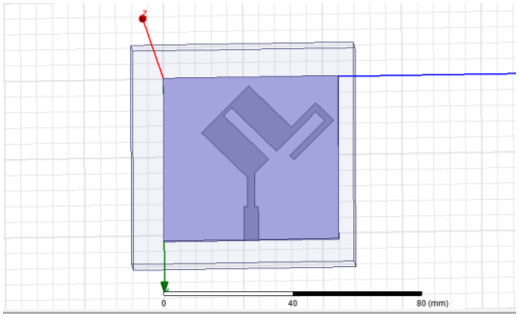


Figure 3 – Quad-Band CP Patch Antenna in HFSS

5. Simulation Results

(i) Return Loss

When a signal is transmitted from the transmitter to a receiver, some part of the signal will be received, and some other part will be reflected the transmitter itself [6]. The return loss should be as low as possible which indicates that the antenna is working in good condition. The return loss should be less than -10 dB, which means the antenna is in proper condition.

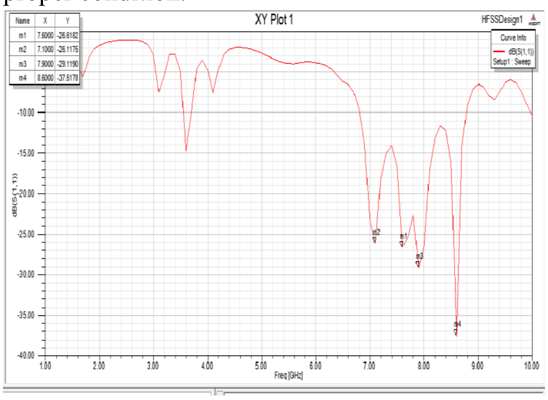


Figure 4 – Return Loss Plot

Tabulation for Return Loss Curve:

S. No	Frequency (GHz)	Return Loss (dB)
1.	7.1	-26.1175
2.	7.6	-26.6182
3.	7.9	-29.1190
4.	8.6	-37.5178

(ii) Radiation Pattern

Radiation pattern describes the directional dependence of the signal strength from the transmitter or any other source. The red colour line indicates the minimum radiation; the blue color line indicates the mean radiation and the purple colour line indicates the maximum radiation from the antenna.

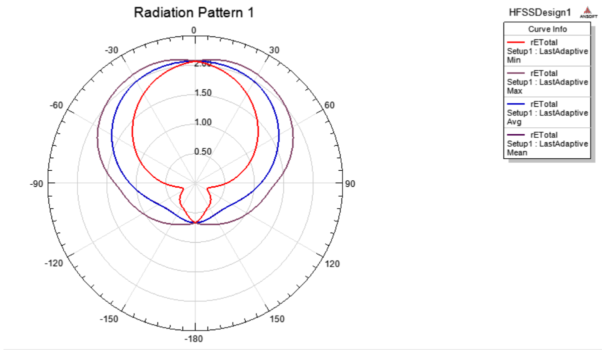


Figure 5 – Antenna Radiation Pattern

(iii) Boundary Assignments

The boundary assignments play a significant role in antenna design. The ground plane and the patch were given a perfect E-field. The radiation box is used to provide an air environment, and it is given an excitation of radiation only. The following figures show the Perfect E-Field of Port and Radiation Boundary of Radiation Box.

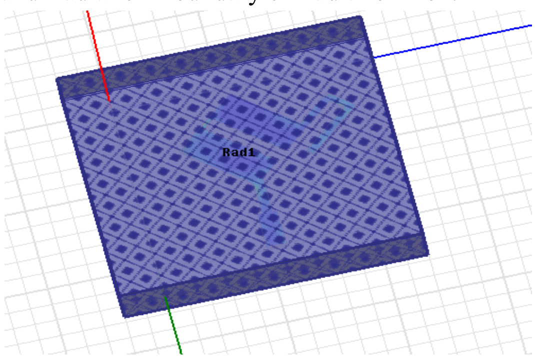


Figure 6 – Radiation Boundary of Radiation Box

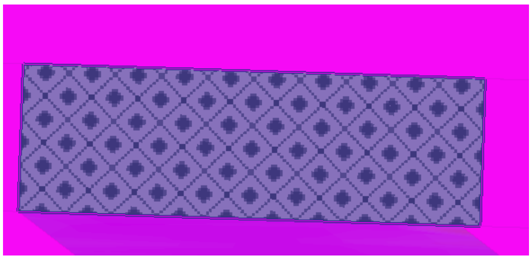


Figure 7 – Perfect E-field of Port

(iv) VSWR

VSWR stands for Voltage Standing Wave Ratio which denotes the reflected signals from the receiver side. It also describes how well the antenna is impedance matched to the radio transmitter or receiver. There are various impedance matching techniques are being used to avoid the reflection loss of signals. Theoretically, we have studied that VSWR should be less than one.

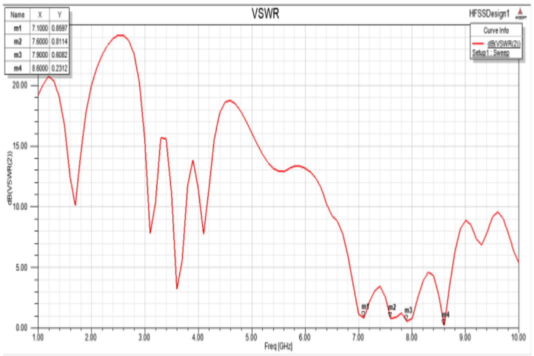


Figure 8 – VSWR curve

Tabulation for VSWR Plot:

S. No	Frequency (GHz)	VSWR (dB)
1.	7.1	0.8587
2.	7.6	0.8114
3.	7.9	0.6082
4.	8.6	0.2312

(v) 3dB Gain

The measured 3 dB AR information is 5.63% (6.9-7.3 GHz), 5.26% (7.4-7.8 GHz), 5.0% (7.8-8.2 GHz) and 3.50% (8.4-8.7 GHz) severally.

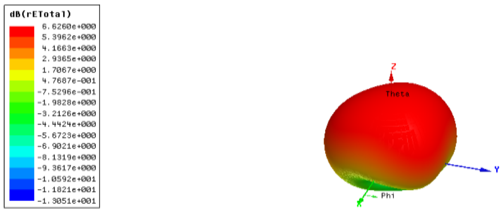


Figure 9 - 3D Polar Plot

(vi) Animated Radiation Pattern

The following figures show the animated radiation pattern of quad-band circularly polarized patch antenna in both the Electric-Field and Magnetic-Field.

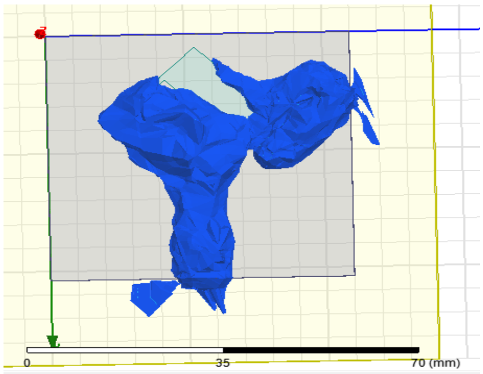


Figure 10 – Animated Radiation in E-field

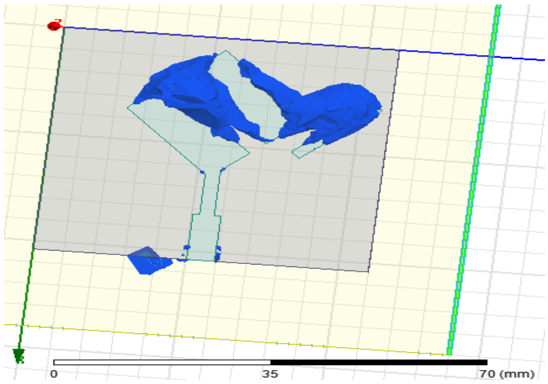


Figure 11 – Animated Radiation in H-field

(vii) 3D Rectangular Plot

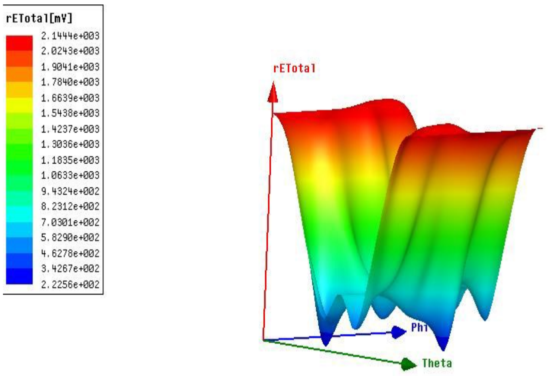


Figure 12- 3D Rectangular Plot

(viii) Axial-Ratio

The axial ratio is used to characterize how well the antenna was circularly polarized.

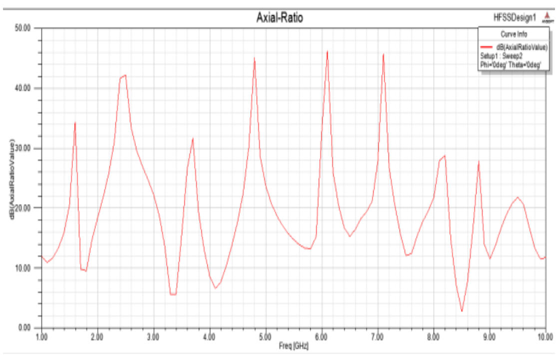


Figure 13 – Axial-Ratio

6. Conclusions

A quad-band circularly polarized patch antenna for 7.1/7.6/7.9 GHz for UWB applications and 8.6 GHz for 5G applications was obtained and characterized. They were achieved by a patch associate antenna composed of an inverted U-shaped radiator with extra L-shaped and I-shaped strips, all turned by 45^{o} around the horizontal axis. The measured 3 dB AR information is 5.63% (6.9-7.3 GHz), 5.26% (7.4-7.8 GHz), 5.0% (7.8-8.2 GHz) and 3.50% (8.4-8.7 GHz) severally.

Upon the conclusion of our paper we made the following assessment of our work:

The overall working of antennas was understood. The significant parameters (such as Return Loss curves, Radiation Patterns, Directivity, and Beamwidth) that affect design and applications were studied, and their implications understood.

The constructed slotted waveguide and quad antennas operated at the desired frequency and power levels. Several patch antennas were simulated (using HFSS) and the desired level of optimization was obtained. It was concluded that the hardware and software results we got the theoretically predicted results.

7. Scope for Improvement

There were some areas we felt we did not address. They were:

- The experimental radiation patterns of the constructed antennas could not be obtained and compared with the general models.
- Though we were able to simulate several patch antennas, we were unable to fabricate one and compare the practical and simulated results.
- A complete study of different field solvers and simulators (such as Sonnet, AWR, IE3D, etc.) could not be made. We were only able to focus on HFSS.

1. Acknowledgment

We are deeply indebted to pay our sincere thanks to our respectable Head of the Department, Dr.I.Manju, Ph.D. Department of Electronics and Communication Engineering for showing some exuberant consent for our research paper and providing us with all the facilities in the department to complete the paper. We take immense pleasure to express our heartfelt thanks to our Guide Mr.A.Sivabalan, M.E for motivating us to study in this field and for his illuminating guidance and continuous support in the planning and execution of this paper.

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