International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 11 Issue 04, April-2022

Design of Multi-band Patch Antenna for 5G, WiFi,Bluetooth, WiMax and WLAN Applications

Manish Rasal
Department of Electronics and Communication EngineeringVisvesvaraya National Institute of Technology Nagpur, India

Erigela Harinath Reddy
Department of Electronics and Communication EngineeringVisvesvaraya National Institute of Technology Nagpur, India

Bandi Anusha
Department of Electronics and Communication EngineeringVisvesvaraya National Institute of Technology Nagpur, India

Mathukumilli Nitin Srinivas Prasad
Department of Electronics and Communication EngineeringVisvesvaraya National Institute of Technology Nagpur, India

Pranjalee Mishra
Department of Electronics and Communication EngineeringVisvesvaraya National Institute of Technology Nagpur, India

Dr. K. D. Kulat
Department of Electronics and Communication EngineeringVisvesvaraya National Institute of Technology Nagpur, India

***Abstract*—This paper presents a design of a multi-band slotted patch antenna which covers Fifth Generation (5G), WiFi(Wireless Fidelity), WiMax(Worldwide Interoperability for Microwave Ac- cess) and WLAN(Wireless Local area network) applications in sub 6 GHz spectrum. The antenna which is designed is able to cover WiFi and Bluetooth frequency which is 2.4GHz , WiMAX band which is from 3.4 to 3.6 GHz, 5G spectrum which is 3.3 to 3.6 GHz and WLAN spectrum from 5.1-5.3 GHz. A triangular micro-strip patch antenna with two horizontal slots and three L shapes is presented. The antenna is designed on Rogers RT/duroid 5880 substrate with dielectric constant of 2.2 and it's dimensions are 56 × 49 × 1.6 mm^3. The simulated results show us that the antenna has return loss of -32dB at 2.4GHz, -26.5dB at 3.4GHz and -27.7dB at 5.27GHz and gain of 4.63dBi, 4.603dBi and 3.709dBi respectively. The simulated efficiency of the proposed antenna at 2.4GHz is 77%, 80% at 3.4 and 73% at 5.27GHz, whereas overall efficiency of the antenna is 76%. The results are in good agreement for wireless applications.**

I. INTRODUCTION

Due to ever increasing growth in wireless communication the demand for mobiles, smartphones and internet of things (IoT) antennas have been increased which requires more bandwidth. Considering the requirements for communication systems, data traffic will also increase by a large amount in the coming future. To overcome these problems, Fifth Generation(5G) communication systems are being designed and deployed. 5G communication assures us a high-speed data transmission rate, reliable low latency communications and high mobility. For the implementation of 5G communication technology, the Federal Communications Commission(FCC) has divided the spectrum into different band, namely low-band, mid-band and high-band. The low-band covers frequencies up to 1 GHz, the mid-band covers from 1-6 GHz and the high- band is the mm-Wave (Millimeter Wave)[1] spectrum. Sub 6 GHz spectrum is ideal band for 5G communication because it provides a high speed of data transmission over long distances.

Antennas are a necessary component of a cellular communication system as they determine the overall performance of the device. With adapting to the new 5G technology, the size of portable communication devices is becoming smaller. Due to which antenna size has become a topic of concern. [2] Instead of designing separate antennas for various applications, it is essential to design a single compact antenna which can cover majority of the requirements with a high performance. [3] This 5G antenna should be able to cover the existing Wireless Fidelity(Wifi), Worldwide Interoperability for Microwave Access(WiMAX) and Long-Term Evolution(LTE) bands in sub-6 GHz spectrum.

The chosen type of antenna also plays an important role in meeting the requirements and determining the overall performance of the devices. [4] Microstrip patch antennas are being explored because they provide better outcomes for multi-band operation than a traditional monopole antenna configurations. The proposed monopole antenna in this paper[5] does not have the requisite bandwidth, and its gain is insufficient.

Patch, substrate, and ground plane are the three basic

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 11 Issue 04, April-2022

components of a micro-strip patch antenna in general. The radiating patch, which is constructed of copper, is bonded to the upper layer of the dielectric substrate, while the ground plane is attached to the lower layer. Due to their conformability and ability to acquire any geometrical shape and dimension, micro-strip patch antennas have been one of the best alternatives for wireless applications.

Considering the simple design and wide range of applications, circular, triangular rectangular micro-strip patch antennas are commonly selected because they allow feed-line flexibility, a wider frequency range, multiple polarisation, and superior bandwidth. The shapes like E, Z, T, S, H, L and F can also be added to micro-strip antennas to give the antenna multi-band characteristics. Micro-strip patch antennas have a number of advantages over traditional antennas, including lower weight, lower volume, lower cost, low profile, smaller dimensions, easy manufacture, and conformance. Micro-strip antennas are utilised in a variety of applications, including radars, telemetry, navigation, radio frequency identification (RFID), biomedical systems, mobile and satellite communications, missile systems and global positioning system (GPS) for remote sensing and etc. Due to its small size and planar shape.

The micro-strip patch antenna should be designed in such a way that it has a wide bandwidth and can be operated in multiple bands present in different spectrums. [7] A multi-band micro-strip antenna is used here but the resonating frequencies for WiMAX and 5G spectrum is not in sub 6 GHz range and the obtained gain value for this particular design is low.[8] A tri-band antenna resonating at 2.4GHz, 3.5GHz and 5GHz frequencies is designed but this antenna has very small gain and less efficiency.

[9,10] There are different techniques to improve the performance and working of an antenna operating in multiple bands, one of which is Defected Ground Structure (DGS). In this technique, different shaped slots will be created in the ground plane to enhance bandwidth and gain. These slots can be of the shapes like rectangle, square, L shaped, etc.

[11,12] Micro-strip patch antennas having multiple slots of different shapes are mentioned here. These slots are etched from the patch which helps the antenna to operate at multiple frequencies. Each slot is having different length which corre- sponds to different frequency of operation. Shape and orien- tation of the slots also plays an important role in determining the performance of an antenna.

II. DESIGN OF THE ANTENNA

Simple patch antenna structures are not suitable for an antenna to operate in multiple band, so to improve the efficiency, gain and overall performance of the antenna a micro-strip patch antenna structure is selected. This antenna is designed in such a way that it has slots etched on the patch and L shaped structures are added at the appropriate places. The proposed multi-slot antenna comprises a triangular patch and a partial ground plane. Fig. 1 and Fig. 2 depicts the front and rear views of the designed antenna. The patch is placed on a side of 1.6 mm thick Rogers RT5880 Duroid dielectric substrate with dimensions as $56mm \times 49mm$ having permittivity of 2.2 and loss tangent value of 0.0009. The ground plane has dimensions of $56mm \times 33mm$. Two horizontal slots of dimensions $2.25mm \times 33.21mm$ and $2.25mm \times 22.81mm$ are etched on the patch. For feeding the designed antenna a 50-ohm characteristics impedance feed- line with the dimensions of imm $il \times mm$ is connected to the patch. Detailed dimensions of the antenna are mentionedin TABLE I.

The electric field flow in an antenna increases by adding L shaped structures. Thus, this increased flow gives better results. The two slots created in the patch helps the antenna to resonate in different frequency bands of sub 6GHz spectrum.

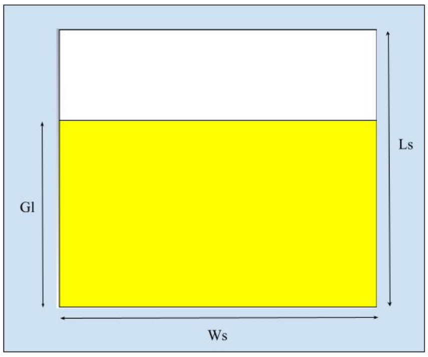

Fig. 1. Back view of antenna

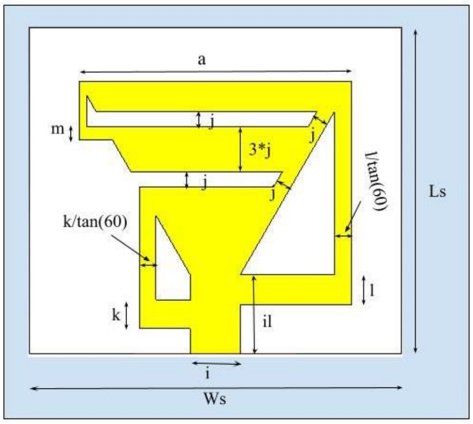

Fig. 2. Front view of proposed antenna

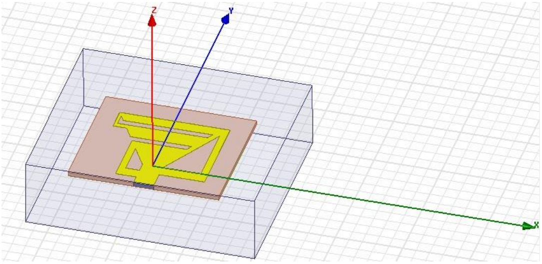

Fig. 3. Antenna simulated in HFSS

Sr. No.	Parameter	Value	Description
1	Ws	56	Width of the substrate
2	Ls	49	Length of the substrate
3	t	1.6	Thickness of the substrate
4	Gl	33	Length of the ground plate
5	a	41	Side of triangle
6	il	11.8333	Length of the feed-line
7	i	7.5	Width of the feed-line
8	l	4.5	width of bigger L shape
9	k	4.3333	Width of medium L shape
10	m	2	Width of smaller L shape
11	j	2.25	Breadth of the horizontal slots

TABLE I
ANTENNA PARAMETERS USED FOR SIMULATION

Computer Simulation Technology (CST) simulator is used to design, analyze and simulate the antenna. Further ANSYS HFSS software is used to cross check the results.

The proposed antenna uses micro-strip line feeding since it is simple to fabricate. The resonance frequencies of the antenna are determined by the length and breadth of the slots as well as the widths of the L shapes. Multi-band features can be altered by changing the values of parameters of the antenna. The values of different parameters are chosen in such a way that it should give optimized results at desired frequencybands.

III. SIMULATION RESULTS

Three distinct resonance frequencies are found after simulating the antenna design in CST software, as shown in Fig. 4. 2.4GHz, 3.4GHz and 5.27GHz are the three resonating frequencies. The applications of these frequencies are listedin the TABLE II.

For the first resonating frequency i.e. for 2.4GHz, the return loss (S11 parameter) is -32dB. For 3.4GHz the return loss is about -26.5dB and for the third resonant frequency which

Sr. No.	Frequency	Application
1	2.4	WiFi and Bluetooth (IEEE 802.16)
2	3.4	5G (Sub 6GHz) and WiMax
3	5.3	WLAN

TABLE II
FREQUENCY ACHIEVED AND IT'S APPLICATIONS

is obtained at 5.27GHz, the return loss is -27.7dB. Whereasthe obtained S11 parameter values in HFSS simulation are
-23.84dB, -35.03dB and -20dB respectively. The Fig. 4 showsthe combined results of CST and HFSS.

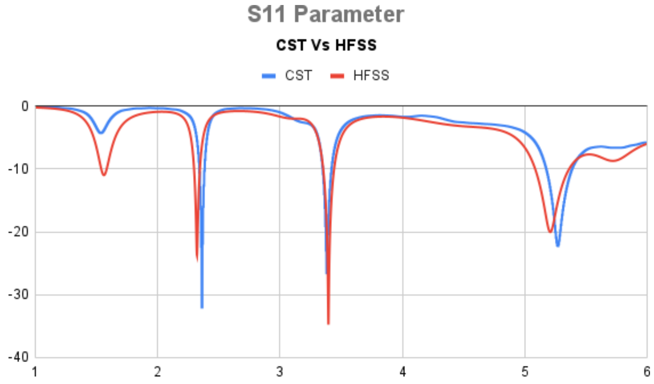

Fig. 4. CST vs HFSS simulated values of S11 parameter

An antenna's gain in a particular direction is defined as the ratio of the intensity in that direction to the radiation intensity that would be achieved if the antenna's power was radiated isotropically. The following figures show the gain of the antenna at obtained resonating frequencies. Generally a multi-band antenna has gain of about more than 3dBi. The obtained gain values after software simulation at 2.4GHz, 3.4GHz and 5.27GHz are 4.627dBi, 4.603dBi and 3.790dBi respectively. Where as in HFSS simulation, the gain values found to be 4.673dB, 4.367dB and 3.206dB respectively. Fig. 5 shows the gain vs frequency graph of the proposed antenna.

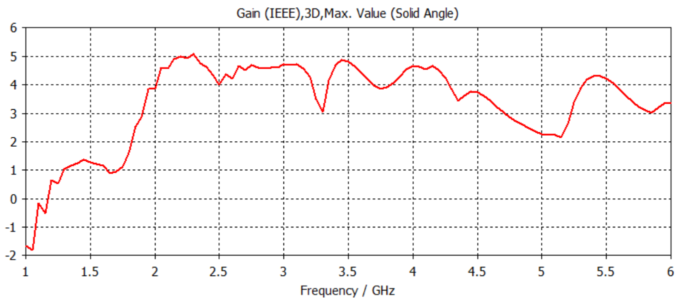

Fig. 5. Gain vs Frequency graph

IV. CONCLUSION

A Multi-band patch antenna which can be operated at three different frequencies and has five different applications is designed and simulated using CST software and the results are cross-checked in ANSYS HFSS software. 2.4GHz, 3.4GHz and 5.27GHz are the achieved resonating frequencies. This is a 5G (sub 6GHz spectrum) antenna which can also be used for the wireless purposes such as WiFi, Bluetooth, WiMax and WLAN. The multi-band performance is obtained after

Ref. Antennas	**Size (mm^3)**	**Resonant frequencies (GHz)**	**Respective Gain**	**Applications**
[2]	50×80×1.5	2.55, 3.5, 4.75	2.52dBi, 3.04dBi, 4.31dBi	5G, WiFi, WLAN
[6]	70×51.6×1.8	3.5, 4.5, 5.8	1.1dBi, 3.4dBi, 5.1dBi	WiMax, WLAN
[9]	20×20×1.6	3.3, 3.85, 5.25	3.4dBi, -2.1dBi, 2.185dBi	WiMax, WLAN
[10]	28×23.45×5.35	4.9	5.49dBi	5G
[11]	20×30×1.5	3.85, 4.71	2.35dBi, 2.69dBi	5G
[17]	30×20×0.8	2.75, 3.34, 5.49	2.1dBi, 2.24dBi, 2.44dBi	WiFi, WiMax
Proposed Antenna	56×49×1.6	2.4, 3.4, 5.27	4.627dBi, 4.603dBi, 3.790dBi	5G, WiFi, Bluetooth, WiMax, WLAN

TABLE III
COMPARISON OF THE PROPOSED ANTENNA PERFORMANCE TO THAT OF REFERRED ANTENNA

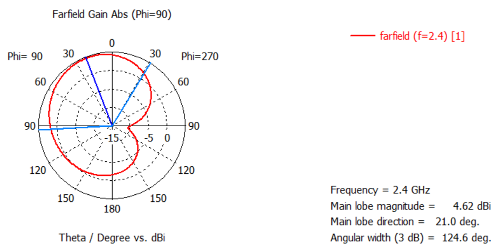

Fig. 6. Simulated polar plot of the proposed antenna at 2.4GHz

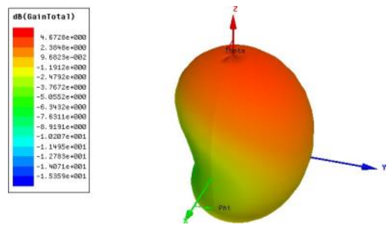

Fig. 9. Simulated 3D radiation pattern of the proposed antenna at 2.4GHz inHFSS

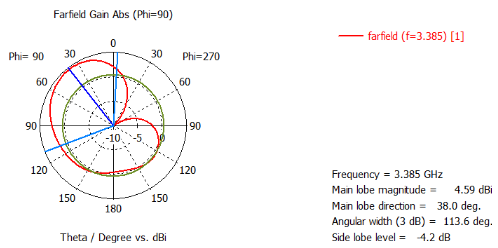

Fig. 7. Simulated polar plot of the proposed antenna at 3.4GHz

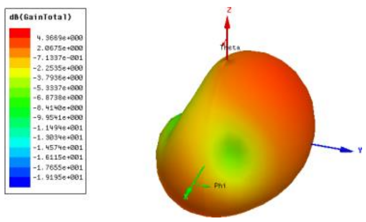

Fig. 10. Simulated 3D radiation pattern of the proposed antenna at 3.4GHzin HFSS

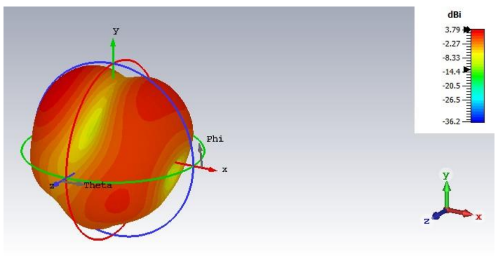

Fig. 8. Simulated 3D radiation pattern of the proposed antenna at 5.27GHz

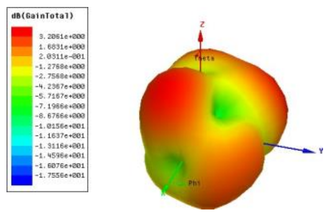

Fig. 11. Simulated 3D radiation pattern of the proposed antenna at 5.27GHzin HFSS

experimenting with the different parameters such as side length of the triangular patch, length and bread of the slots and the L shapes etc. The location and the orientation of slots and L shapes also affect the performance of the antenna. All the obtained frequencies have acceptable values of return losses (S11 parameter), other characteristics and have good efficiencies. For future simulation process, other shapes such as circular/semicircular patch, H shapes, E shapes can also be implanted in order to achieve more frequencies and to reduce antenna size.

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