DESIGN OF COMPACT MULTIBAND MICROSTRIP PATCH ANTENNA FOR 5G WIRELESS COMMUNICATION

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ABSTRACT:

In this work , we proposed a multiband antenna of small footprint area.The antenna having dimension of $30*30*1.6mm^3$. The proposed antenna resonates at triple band. The first two band cover n77,n78 and n79 band of 5G NR. The proposed antenna designed using low cost FR-4 substrate material. The three resonating frequency are 3.86,5.22 and 6.82 GHz. The ground has L shaped slot to improve the gain performance.The gain obtained at desired resonating frequency are1.36, 2.63, 0.47dBi. The radiation efficiency obtained are 95,97 and 97 %. From the simulated analysis it is confirmed to best for 5G and C-band application.

Keywords—Band-width; microstrip; multi-band; notch slot; rectangle slot; 5G

Introduction:

The demand for high-speed wireless communication systems has been growing rapidly with the advent of 5G technology. The advancement in wireless communications technology will go further

and its applications range also vary. The difficulty or challenge in current wireless communication is the availability of required or suitable frequency. To meet this demand, the need is design and optimization of a multiband microstrip patch antenna suitable to be integrated into hand held device.The key challenges are to achieve multiple operating frequencies within the 5G spectrum and other applicationwith reduced physical footprint of the antenna.. Compact size antennas save space, making them suitable for integration into small and portable 5G devices. Microstrip patch antennas are known for their low profile and can be easily integrated into the design of modern devices Multiband antennas are often at reasonable or affordable cost to manufacture due to their smaller size and simpler design, making them economically viable. [1-5] Compact size of antenna is used to incorporate the antenna in small devices such as smartphone, IOT devices. 5G is used to provide high data rates and low latency compared to previous generations.. The Mid-band spectrum ranging from 1GHz - 6GHz is considered as suitable frequency band for 5G wireless communications. As the demand for 5G wireless communications is increasing day by day, the rate of data transmission has to be increased.The microstrip patch antennas are integrated on printed circuit board surface for 5G cellular devices. These antennas have more advantages such as less weight, reduced size and low cost. There are different antenna types for different 5G frequency bandsgiven inliterature [5-25].

The design with constant patch geometry and feeding mechanism whereas substrate and patch material consists of some variation that is illustrated in [1] and also finite element method-based full wave high-frequency structure simulator is used for simulations followed by fabrication and testing of antenna. A 4 element MIMO antenna with transparent conductive sheet used in the ground plane (AgHT-8 and Plexiglas), which attains maximum percentage of optical transparency with sufficient amount of impedance bandwidth at targeted frequency bands with improved values of gain and efficiency [2].The slotted structure that is introduced in the antenna facilitates wireless applications , the antenna has two radiation patterns that is omni-directional and bi-directional at two different frequencies 2.4GHz and 3.77GHz respectively which is discussed in [3]. Another design of antenna [4] that is compressed so that the width of the antenna is small, circular in shape which exhibits less delay, low cost, better speed and also characteristics of wide band. The substrate material used in [6] is FR-4 (lossy) which has dielectric constant 4.3 , antenna can be used for wireless communication at different electromagnetic spectrum's L, S, C frequency bands. The design of antenna proposed in [7] covers multiple frequencies, return loss at each resonant frequency is less than -14dB and gain is greater than 5 and these results are sufficient and show better performance for wireless communications. The introduction of 3 pairs of notches for the antenna proposed in [9] in order to resonate at more frequency bands,it operates at 27.3GHz and 49.2GHz for cellular network applications; and 60.75GHz and

75.38GHz for WiGig applications and also it has high gain at different operating bands that facilitates 5G applications. The material used for designing antenna is RoggerRT/Duroid 5880 with dielectric permittivity 4.3, reducing S-parameter and to get standard VSWR with a value equal to 2 or close to 1 , the improvement in antenna's directivity gain and to get sufficient bandwidth , these are the main motives of [11]. Loss of power in antenna [12] has been reduced by efficient utilisation of parameters, gain is improved with greater value and less value of VSWR and return loss is achieved. [13] represents a super wideband antenna with slotted Y shape for 5G communication, this antenna is designed with ROGERS RT6002 substrate material with miniaturized dimensions and also the antenna consists of moderately stable value of efficiency and gain.Microstrip patch antenna with U slot and 2 paratactic elements is designed and simulated, U shaped slot is used to produce a circular polarisation that is illustrated in [14], the process is carried out with Finite Element Method that is verified with Finite Integration Technique. The patch antenna loaded with super compact parasitic patch with more wideband and enhanced gain for 5G millimetre wave, [15] consists of hybrid geometry.Theantenna radiator consists of a new fractal structure which is similar to tree in nature, the proposed antenna [16] has adopted two iterations with its fractal structure one is for mobile applications and another is for Bluetooth frequency bands. The proposed microstrip patch antenna in [17] has reduced size for millimetre wave applications, for appropriate use of 5G the antenna consists of stable radiation pattern, wide bandwidth and enhanced reflection coefficient at 24.5GHz. The antenna in[18] has reduced dimensions with the use of rectangular and circular patches all together designed in one substrate, it offers multiband operation at two different frequency bands due the resilient coupling between parasitic and driven patches.[19] consists of survey on multiband and multi-generation of 5G antennas, patch antennas are suitable to providerequired amount of latency and throughput.

Design Evolution:

Stage-1: This stage consists of Microstrip patch antenna , the dimensions of patch antenna is illustrated in table-1. The below consists of graph and gain plot of this stage. In this stage only single band is obtained at 6.65GHz frequency with return loss of value -7.82dB and gain is 5.34 dB.

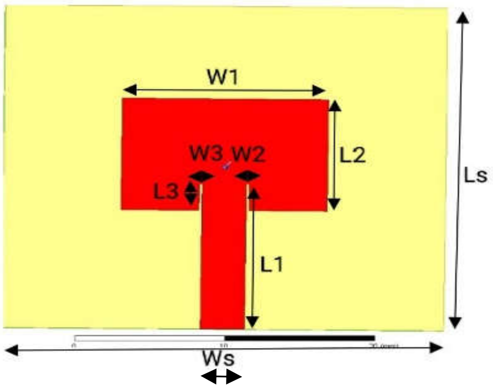


Figure 1.1 :Basic microstrip patch antenna.

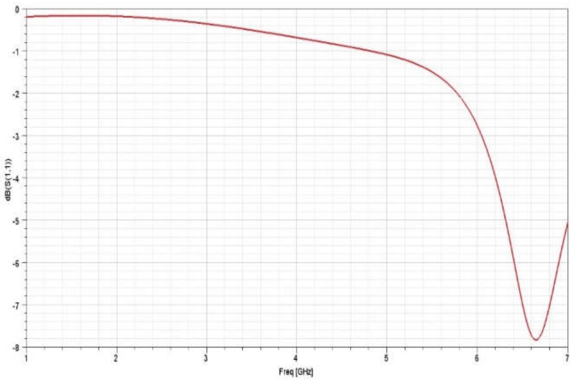


Figure 1.2 : S(1,1) parameter for basic Microstrip patch antenna.

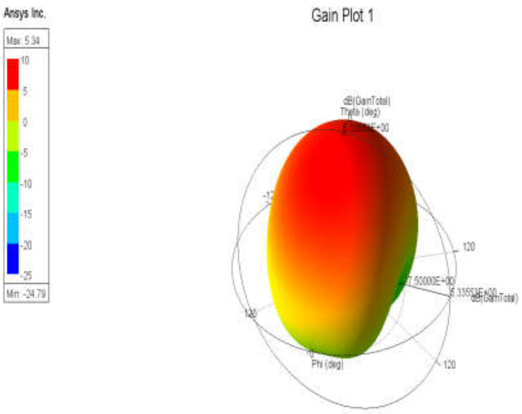


Figure 1.3 : Gain obtained for microstrip patch antenna

Stage-2: In this stage the design of previous stage patch is modified , the dimensions of the cut are illustrated in table-1. . The below consists of graph and gain plot of this stage. In this stage , the return loss is -18.1dB and -10.3dB at frequencies 5.17GHz and 6.33GHz respectively and the gain is 4.77dB.

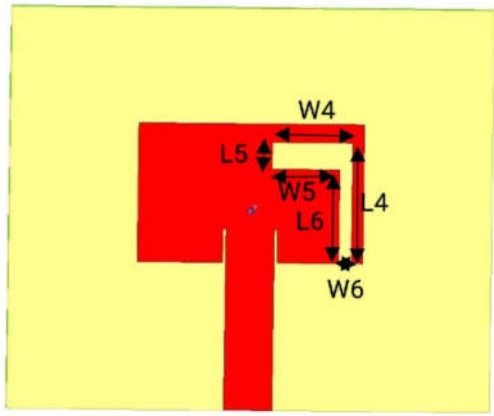


Figure 2.1 : Modified microstrip patch antenna (Stage-1).

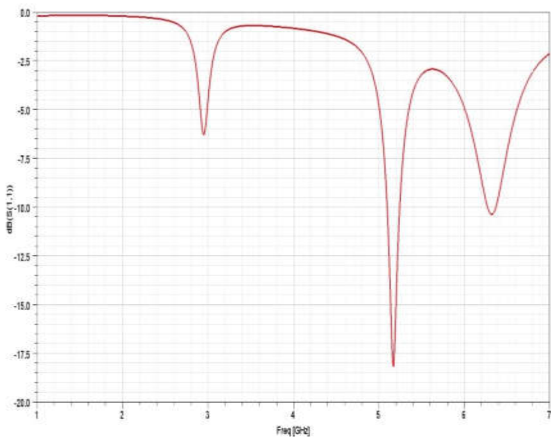


Figure 2.2 : Graph of modified microstrip patch antenna (Stage-1).

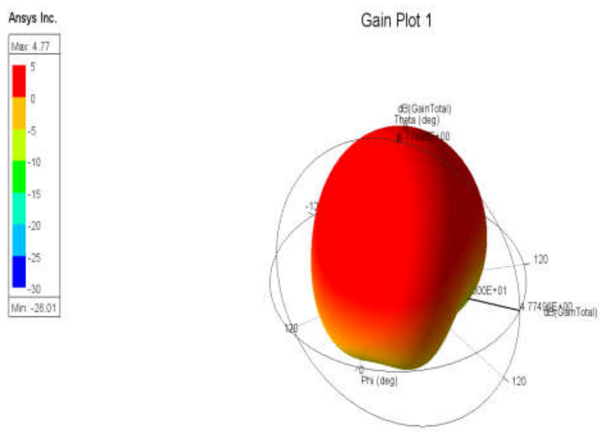


Figure 2.3: Gain obtained for modified microstrip patch antenna (Stage-1).

Stage-3: In this stage the design of previous stage patch is modified , the dimensions of the cut are illustrated in table-1. . The below consists of graph and gain plot of this stage. In this stage , return loss is -23.5dB and -18.8dB at frequencies 4.01GHz and 5.64GHz respectively and the gain is 4.09dB.

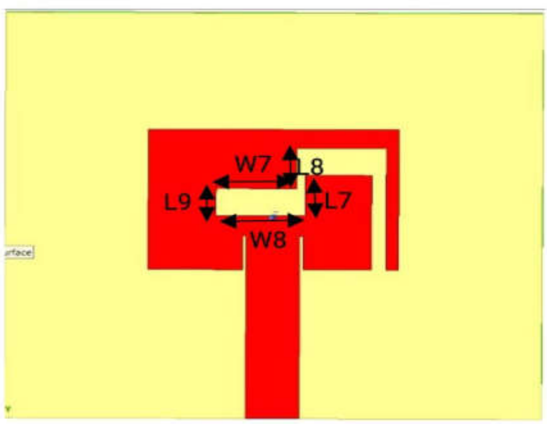


Figure 3.1 : Modified microstrip patchantenna (Stage-2).

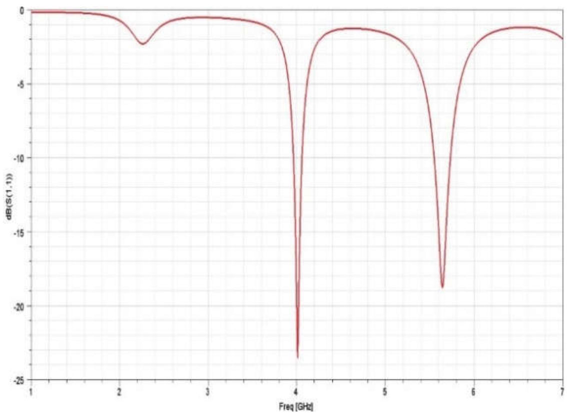


Figure 3.2 : Graph of modified microstrippatch antenna (Stage-2).

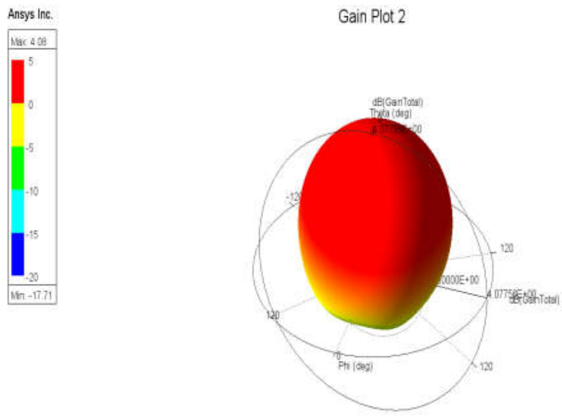


Figure 3.3: Gain obtained for modified microstrip patch antenna (Stage-1)

Stage-4: In this stage the design of previous stage patch is modified , the dimensions of the cut are illustrated in table-1. The below consists of graph and gain plot of this stage. In this design , return loss is -22.7dB , -18.4dB and -16.9dB at frequencies 3.86GHz , 5,22GHz and 6,82GHz respectively and gain is 2.63 dB.

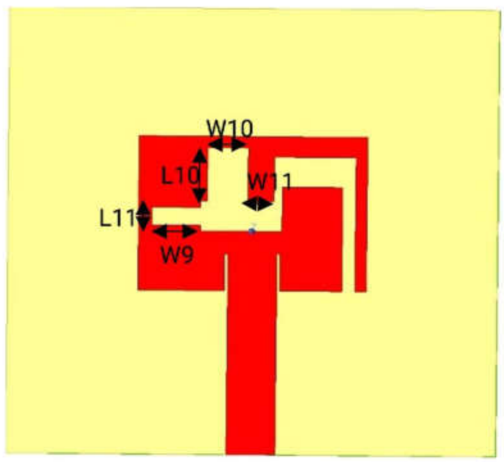


Figure 4.1 : Modified microstrip patch antenna (Stage-3).

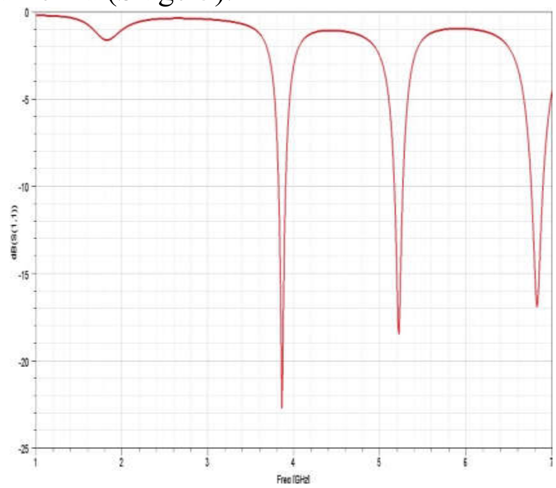


Figure 4.2 : Graph of modified microstrippatch antenna (Stage-3).

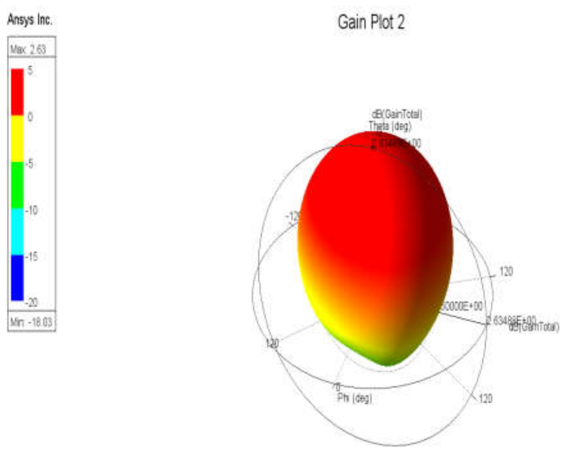


Figure 4.3: Gain obtained for modified microstrip patch antenna (Stage-3)

In stage-1 , single band is obtained our target is to get triple band , so the stage-2 is evolved but here the return loss is not upto the mark that is the return loss is greater than -15dB but it has to be less than -15dB. The evolution of stage-3 takes place but it is dual band so in stage-4 it has triple band

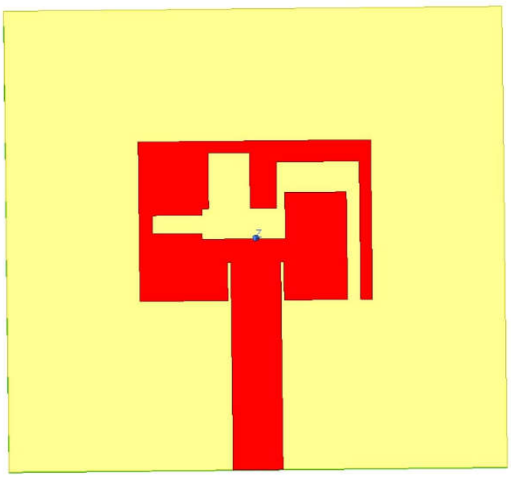
but the gain is appropriate .

Parameters	**Value(mm)**
Ls	30
Ws	39
L1	15
W1	14
L2	10.38
W2	0.2
L3	2.5
W3	0.2
L4	9
W4	5
L5	2
W5	3.7
L6	7
W6	0.8
L7	3
W7	2
L8	8
W8	5

L9	2
W9	3
L10	3.62
W10	2.5
L11	1.2
W11	4.8

Design dimension:

The length of the substrate is same as the length of ground that is 30 mm. The width of substrate is same as width of the ground and it is 30mm. The height of the substrate is 1.6mm. Length of the patch is 10.38mm and width of patch is 14mm. The length of feed is 15mm and width of feed is 3mm.



Top view of antenna design

We designed a microstrip antenna of small footprint that operates in triple band.The microstrip patch antenna is simulated with the help of ANSYS HFSS. Inset-fed structure type of fed of all antenna printed on the dielectric constant of 4.4 , various ground plane length and width, various substrate height and fabricated on the FR4 epoxy substrate due to its low cost and easily available.We designed a microstrip patch antenna by using HFSS software , the operating frequency is 6.5 GHz.Here we used microstrip line feed.Microstrip patch antenna formulas :

- Patch width(W)= $\frac{c}{2f_o\sqrt{\frac{\varepsilon_r+1}{2}}}$

  Where Ɛr=2.2, c=3x10^8 m/sec, fr= 6.5GHz

- Patch length(L)= $\frac{c}{2f_o\sqrt{\varepsilon_{eff}}}$ −0.824h $\left(\frac{(\varepsilon_{eff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{eff}-0.258)\left(\frac{W}{h}+0.8\right)}\right)$

  where $\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[\frac{1}{\sqrt{1+12\left(\frac{h}{w}\right)}}\right]$

- Length of the ground(L_g)=6h+L

Width of the ground(W_g)=6h+W

Return loss:

Return loss in an antenna refers to the amount of power reflected back to the source, it is measured in decibels(dB). It is important because the efficiency of the antenna is known by the amount of power transmitted by the antenna or power received from the source.

$$RL(dB) = -10\log_{10}(P_{reflected}/P_{incident})$$

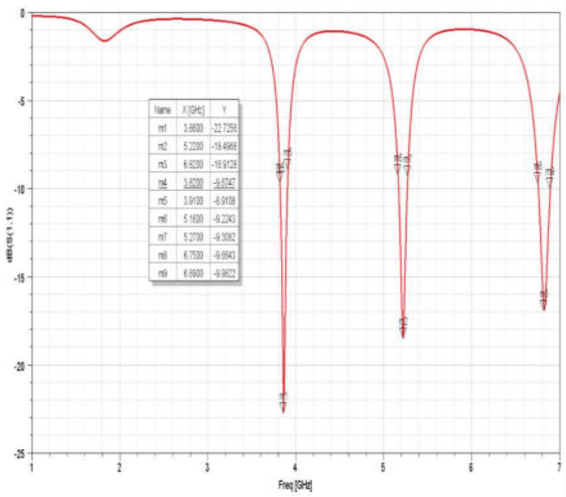


Figure 6: S(1,1) parameter graph.

Gain:

Gain of an antenna represents the ability of an antenna to direct or reflect the radio frequency signals in a part direction while receiving or transmitting signal. Gain of an antenna is measured in decibels (dB) , it is the ratio of power radiated in a particular direction to the power radiated by an isotropic radiator (dBi) .Antenna design can be varied depending upon antenna design, frequency and polarization.

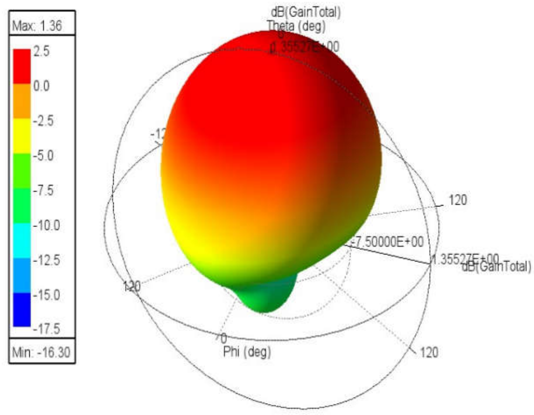


Figure 7.1- Gain of 1st band at 3.86GHz.

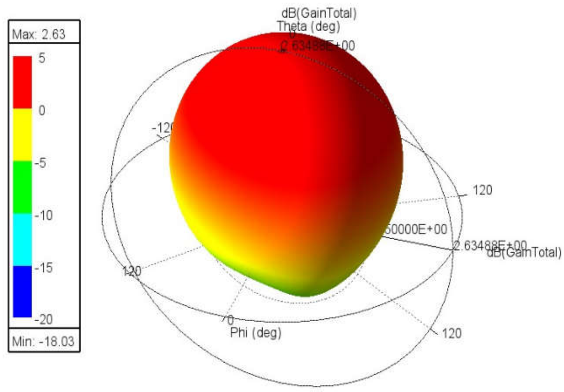


Figure 7.2- Gain of 2nd band at 5.22GHz

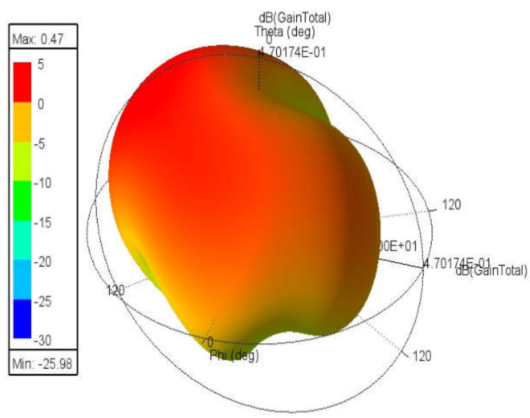
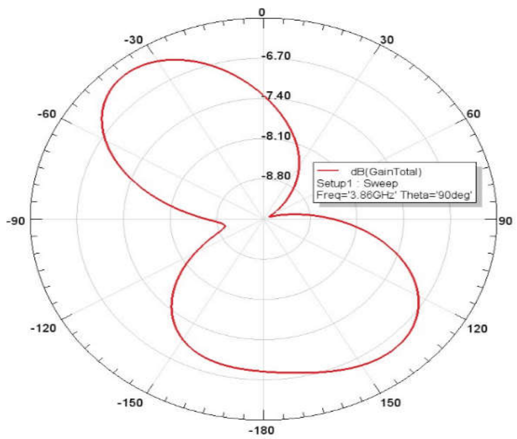


Figure 7.3 – Gain of 3rd band at 6.82GHz.

Radiation Pattern:

The radiation pattern of an antenna is used to describe the directional properties of its radiation in 3d plane. It is measured in both azimuthal and elevation planes in order to get the radiation in all directions.Main lobe is highlyradiated .



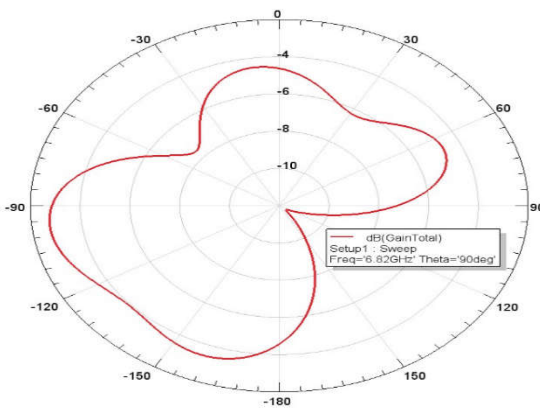


Figure 8.3- Radiation pattern at 3rd band.

Figure 8.1- Radiation pattern at 1st band.

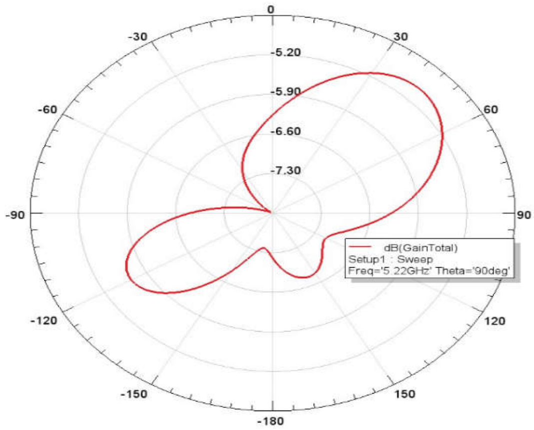


Figure 8.2- Radiation pattern at 2nd band.

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3D Gain:

It refers to three dimensional gain, both azimuthal and elevation planes radiation pattern has to be considered. Antenna gain has to evaluated by considering radiation pattern of full sphere surrounding the antenna. Considering 3D Gain is important for the antenna having application such as full coverage area that extends in different directions.

VSWR Graph:

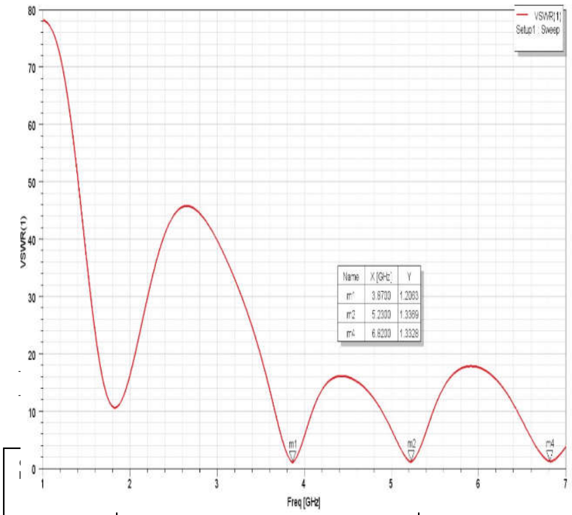

Figure 9- VSWR graph

[illegible]	[illegible]	..oss(dB)	Bandwidth(GHz)	Gain(dB)
1.	3.86	-22.7	3.82 - 3.91	1.36
2.	5.22	-18.4	5.16 - 5.27	2.63
3.	6.82	-16.9	6.75 – 6.89	0.47

Comparison table between proposed antenna and antenna of other references:

Ref., Year	Total no. of bands	Size in mm	Resonant frequency in GHz	Gain in dBi	Return Loss in dB
[1],	Triple band	58x78x0.9	4.2, 4.7, 5.4	3 (average)	-22.5 ,-18 , -24
[3]	Dual band	15x18x1.6	2.4, 3.77	1.43 ,1.29	-15,-18
[12]	Single band	60x65x1.6	2.39	6.66	-13.8
Proposed antenna	Triple band	30x30x1.6	3.86, 5.22, 6.82	1.36, 2.63 ,0.47	-22.72 , -18.49 ,-16.91

Conclusion:

The size of antenna has been reduced that is the length and width are 30mm and 30mm. FR-4 is the substrate material used to design antenna which cost effective. Due to its small size it can be used in IOT devices and smartphones .The antenna is capable of operating across multiple frequency bands, catering to the diverse requirements of 5G wireless communication standards. This enables seamless connectivity and improved network performance in various deployment scenarios.Its compact size makes it suitable for integration into small communication devices and infrastructure, facilitating the deployment of 5G networks in urban environments where space constraints are prevalent.Through innovative design techniques and material selection, the antenna achieves high efficiency and radiation characteristics, ensuring reliable signal transmission and reception for 5G applications.The design methodology employed allows for flexibility in tuning the antenna's operating frequencies and bandwidths, thereby accommodating future advancements and spectrum reallocation in the 5G landscape.The simplicity of the antenna's design and manufacturing process contributes to its cost-effectiveness, making it an attractive solution for mass deployment in 5G communication systems.

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