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Design of Flower Shaped MIMO Antenna for Sub 6-Ghz 5g Applications

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Abstract - In this project, the main aim is to do the simulation of a microstrip patch antenna (MIMO antenna) and to analyze various factors like gain, directivity, return loss, radiation intensity for the frequency of 4 GHz. The simulation of this MIMO antenna is carried out in ANSYS HFSS v2021. Results like return loss, radiation pattern, 3D polar plot, beamwidth, radiated power, accepted power have been obtained using HFSS v2021. the performance. The proposed structure uses FR-4 material with a dimension of 25 mm × 38 mm. The 2 × 1 MIMO structure resonate at 4 GHz for the sub 6 GHz 5 G communications with directional radiation pattern. The resonating frequency is 4GHz, the return loss is -11.7977 and the isolation loss is -61.5343. In addition the performance of diversity system of MIMO structure including the total active reflection coefficient (TARC), multiplexing efficiency, envelope correlation coefficient (ECC) (0.03) and diversity gain (DG) at 9.99 are studied. For this proposed MIMO structure all antenna parameters are found that within an acceptable range.

Key Words: MIMO antenna, Return loss, Envelope correlation coefficient

1. INTRODUCTION

MIMO is a communication technology which uses multiple antennas both at transmitter side and receiver side to transfer more data at a time. Main advantage of MIMO is the transmitted wave will reach the receiver antenna multiple times at different time because of multipath transmission where transmitted wave bounces of walls, ceilings and other objects and this is called Radio-Wave phenomenon. MIMO allows multiple antennas to send and receive multiple spatial streams at same time. MIMO technology leverages multipath behavior by using multiple “smart” transmitters and receivers. MIMO combines the data streams arriving from different paths and at slightly different time to effectively increase the receiver’s signal capturing power, hence this makes the antenna to work smarter. Since MIMO uses multiple antennas, wireless technology is able to considerably increase the capacity of a given channel, the throughput of the channel is increased in increasing the receive and transmit antennas. This make MIMO as an important technology in upcoming wireless communication system
Metamaterial antenna design has size five times smaller with wider bandwidth.

1.1 DESIGN EQUATION

The following are the formulae required to design MIMO antenna:

- $\mathrm{Fr} = \frac{17.8}{l1+l2+g+.\frac{b1}{2\pi\sqrt{\varepsilon r+1}}+\frac{b2}{2\pi\sqrt{\varepsilon r+1}}} = 4\ \mathrm{GHz}$
- $l_1 = L_{g1} + L_{g2} = 16$
- $l_2 = L_{g1} + L_{g2} = 16$
- $B_1 = 3[(L_{g2}+2L_{g1} - L_g)W_{g2}+ W_{g1}. R_{g1}]+ W_g L_g- R_{g1}(L_g- L_{g1}) = 19$
- $B_2 = L_{p1} W_{p1} + {}^{1}/_{4}[W_{p2}(L_{p1}- L_{p2})]+ L_f W_f = 19.$

These equations are designed as per Gorre Naga Jyothi Sree et al.[1].They proposed MIMO antenna structure utilizes a fractal design with microstrip feeding, incorporating a flower-shaped construct with rectangular strips and circular, rectangular slots in the ground plane to reduce isolation between antenna elements. The paper aims to enhance signal scattering and optimize performance. The antenna, constructed using FR-4 material with dimensions of 25 mm × 38 mm, resonates at 3.5 GHz. The paper investigates various antenna performance characteristics, including surface current distribution, radiation patterns, S-parameters, and the performance of the diversity system, which includes metrics like total active reflection coefficient (TARC), multiplexing efficiency, envelope correlation coefficient (ECC), and diversity gain (DG). The results indicate that the proposed MIMO antenna meets the desired performance criteria for 5G applications.

Zamir Wani et al.[2]., proposed (MIMO) antenna for 5G applications. This antenna is compact with a size of 11.3 mm×31 mm excluding feed lines. The radiation patterns of the antenna show pattern diversity in the azimuthal plane, and each antenna element has an end-fire gain about 10 dBi by employing an array of metamaterial unit cells. The isolation between the antenna elements with edge to edge separation <λ0/5.5 at 28 GHz is enhanced by trimming the corners of the rectangular high refractive index metamaterial region along with a ground stub between antennas. The proposed antenna is fabricated, and each antenna element has return loss, Snn<-10 dB with isolation, Snm>21 dB in the frequency range 26 GHz to 31 GHz, which makes this antenna potential candidate for MIMO application at 28 GHz band enabling 5G cellular communications.

Dr. G.K.D. Prasanna Venkatesan et al.[3].,proposed the 2X1 (Multiple Input Single Output) and 2X2 (Multiple Input Multiple Output) configurations for 5G wireless communication. The focus is on improving antenna parameters

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such as bandwidth, gain, VSWR, and return loss using microstrip line feeding. In conclusion, the 2X2 MIMO microstrip antenna configuration shows improved performance, with a gain of 6dB, a bandwidth of 0.7GHz, and a return loss of -32dB. This design is considered promising for 5G applications.

Akash Buragohain et al.[4].,proposed the design of a four-element Multiple-Input Multiple-Output (MIMO) antenna array tailored for 5G applications. The antenna operates within a frequency range of 1.6–4.4 GHz, covering 5G new radio (NR) bands n77 (3.3–4.2 GHz) and n78 (3.3–3.80 GHz). The design incorporates orthogonally placed antenna elements to enhance isolation. Various techniques, such as defected ground structures (DGS) and parasitic elements, are employed to reduce mutual coupling. The proposed antenna is designed using FR-4 substrate and boasts a compact size. It exhibits favorable characteristics, making it a potential candidate for MIMO applications in 5G wireless communication.

Ashfaq Ahmad et al.[5].,proposed the design Multiple-Input Multiple-Output (MIMO) antenna system for 5G communication operating at 29 GHz. This MIMO antenna employs two radiating elements with slits in the radiators to reduce mutual coupling and improve isolation. The compact design measures 11.4 × 5.3 mm², making it one of the smallest 5G antennas to date. The research uses Roger's 4350B laminate as the substrate material and reports low mutual coupling, a low envelope correlation coefficient (ECC < 0.001), and high diversity gain (DG > 9.8 dB) at 29 GHz. The study investigates the antenna's performance in terms of S-parameters, diversity gain, radiation patterns, and envelope correlation. The results indicate a significant improvement in isolation compared to straight antenna elements, which is crucial for efficient 5G communication.

2. Method of design

The design of antenna focused at 4 GHz.The parameters are set as follows:

Length (Lg) : 25 mm

Width (Wg): 38 mm.

FR4 substrate is chosen with thickness of 1.6 mm.

Table 1 : Dimensions of the patch

Parameters	Value
Length (Lp)	16
Width (Wp)	19
Length of the feed (Lf)	10
Width of the feed (Wf)	2.5
Flower patch	
Radius of inner circle	1.5
Radius of outer circle	3

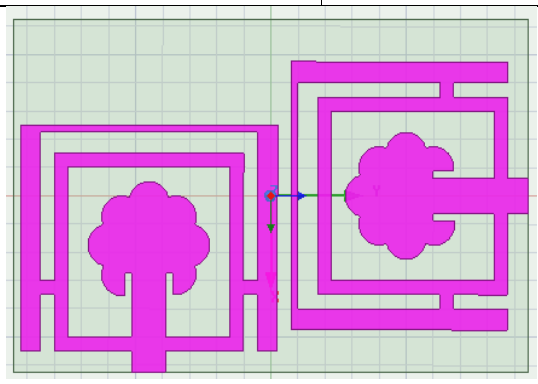

Figure 1 : MIMO antenna with orthogonal polarization

3. Results and Discussions

By designing the antennas in orthogonal polarization mode, the results show that the Return loss at the frequency of 4 GHz is -14 dB.

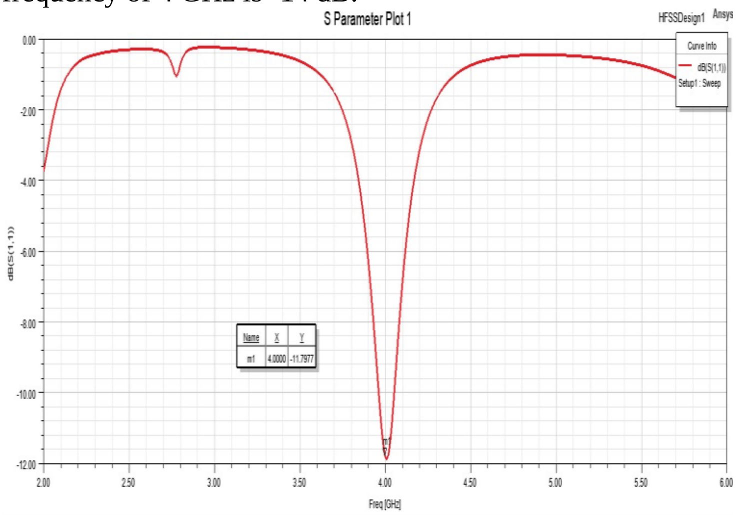

Figure 2 : Return loss

but this design yields high VSWR nearly 6.5,

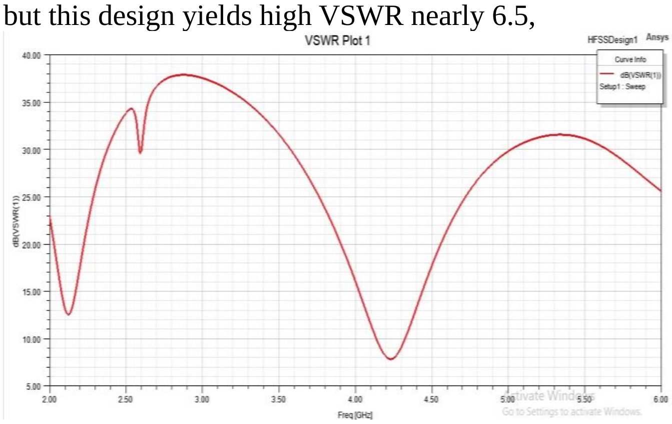

Figure 3 : VSWR

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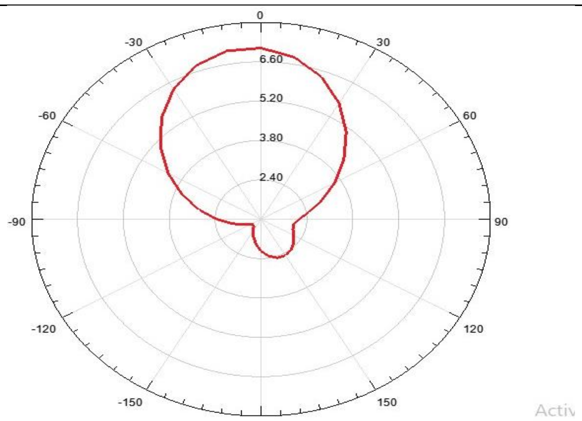
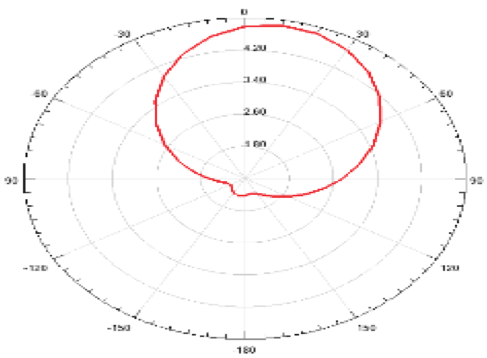
Whenever MIMO antennas are designed it must be tested for isolation loss. It is analyzed in different lengths and widths. Isolation loss at different lengths and widths are analyzed in Table 2.

It shows its maximum value when length and width of the patches are 13.68,16.28 mm respectively.

Table 2 : Isolation loss

Length of the Patch	Width of the Patch	Width of the feed line	Frequency (in GHz)	Isolation loss (in dB)
16	19	2.5	4	-61.5343
15.2	18.05	2.375	4.2	-52.4130
14.4	17.14	2.256	4.3	-57.1787
13.68	16.28	2.143	4.53	-76.7230
12.99	15.46	2.03	4.7	-58.8730
12.34	14.68	1.92	4.88	-54.5067

Table 3 : Radiation field analysis

DIMENSIONS (in mm)	**WITH H FIELD (Phi=90 degree)**
Lp= 16 Wp=19 Wf = 2.5	
Lp = 15.2 Wp = 18.05 Wf = 2.375	

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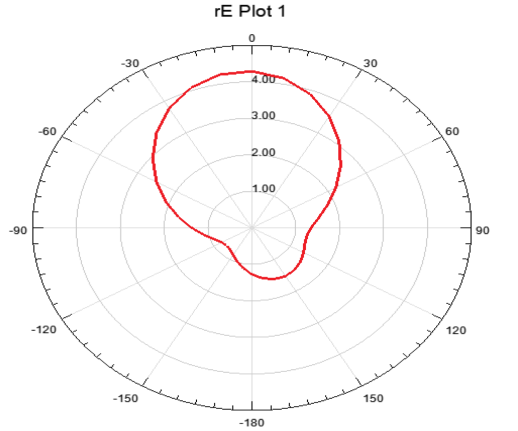
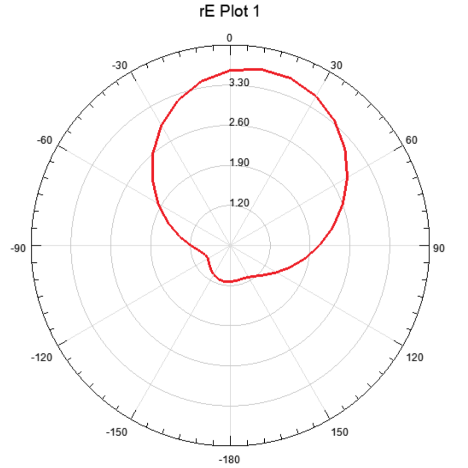
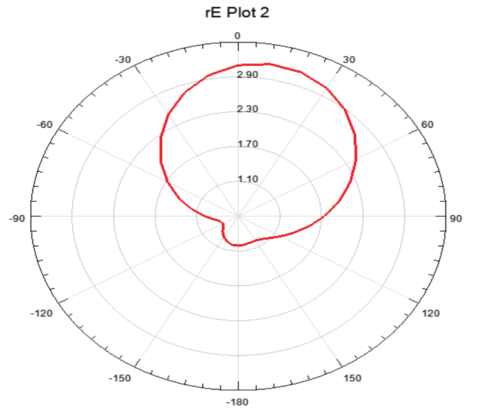
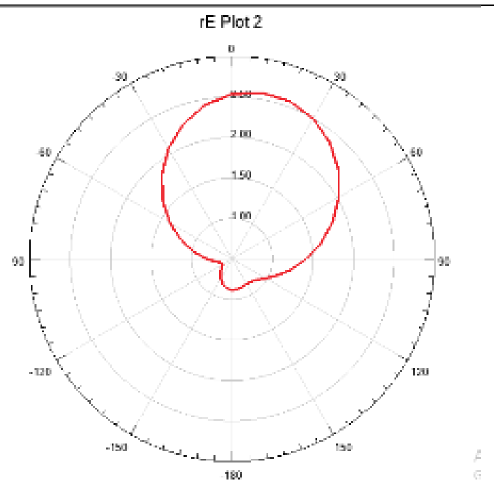
Lp = 14.4 Wp = 17.14 Wf = 2.256	
Lp = 13.68 Wp = 16.28 Wf = 2.143	
Lp = 12.99 Wp = 15.46 Wf = 2.03	
Lp = 12.34 Wp = 14.68 Wf = 1.92	

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Gain and directivity for the above structure is found as shown in Figure 4

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Figure 4 : Gain and directivity patterns

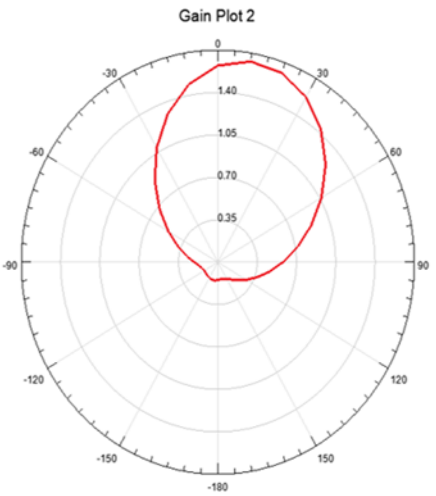
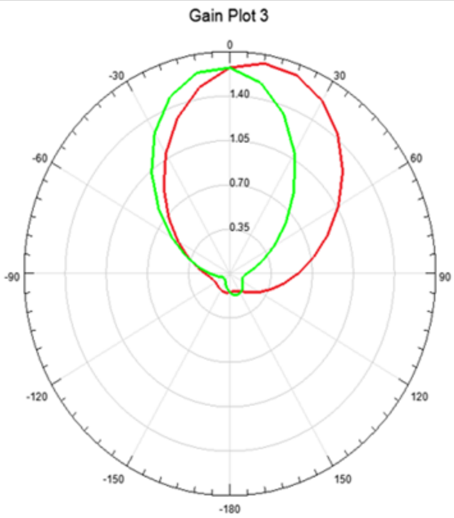
PLANE	E-FIELD (PHI=0 degree)	H-FIELD (PHI=90 degree)
PROPOSED STRUCTURE		

Table 4: Other measured parameters

PARAMETERS	VALUES
PEAK DIRECTIVITY	3.7364
PEAK GAIN	1.7563
RADIATED POWER	231.4 mW
MAX RADIATION INTENSITY	68.801 mW/sr
RADIATION EFFIENCY	47%

3. CONCLUSIONS

The MIMO antenna is mainly used in wireless communications. It is used in high bandwidth communication. It is used in WLAN (Wireless Local Area Network). This MIMO antenna using microstrip line feed is simulated in Ansys HFSS v2021. According to the simulated results the return loss is -11.7977dB at 4 GHz and gain is 2.3dB for the MIMO antenna. The current MIMO structure interference is very low value due to diversity gain at 9.992 , ECC is maintained<0.039 and isolation loss is -61.5343.Thus the designed antenna can be used for 5G applications. Thus, optimization of the antenna properties is done successfully over the HFSS software platform.

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