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Design and Implementation of Dual-Band MIMO Antenna Array for 5G Mobile Applications

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Abstract: *A small dual-band multiple-input-multiple-output (MIMO) antenna for 5G mobile communications is presented in this study. Its element is a dual-band patch antenna working at 3.7 GHz and 4.9 GHz. The dual-band resonance obtained by using T-shaped strip is attached to patch element.The proposed antenna size is 28 mm × 68 mm × 1.6 mm^3.The proposed work is going to develop better MIMO dual band antenna for 5G NR New Radio Applications in Mobile Terminals. It aims to designing of Dual-Band MIMO Antenna Array for 5G Mobile Applications with good isolation. The other aspects or parameters of the antenna will also be analyzed. The proposed dual band MIMO antenna has been designed on FR4 substrate with dielectric constant εr = 4.4 and 1.6 mm thickness. The targeted dual band frequency of MIMO antenna in the range between 3.2 -5.0 GHz. The design and simulation can be done with help of Electromagnetic Simulation tools such as High-Frequency Structure Simulator (HFSS). The dual band MIMO antenna that has been suggested is suited for 5G mobile communications.*

Keywords–Metallic stub, Dual-band,5G Communication, MIMOand Mutual coupling.

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I. INTRODUCTION

Multiple transmit and multiple receive antennas has emerged as one of the most significant technical breakthrough in next generation wireless communications [1] [2] [5]. Wireless communication technology has advanced at a rapid speed in recent decades. At the same time, lots of new issues arose in response to increased demand for better and quicker data transfer. Furthermore, as the fifth-generation (5G) mobile communication standard is developed and built, more and more research into associated technologies is being conducted in the hopes of achieving faster transmission rates, lower costs, and greater gain. The key to achieving a greater transmission rate is MIMO technology [1] [2]. We can build numerous independent channels on the original spectrum using MIMO technology and reduce multipath fading, hence increasing data transmission rate [1] [2].

The fifth-generation (5G) communication technology can provide many advantages such as higher transmission rate and shorter latency over the current 4G system [2].

In order to suppress the mutual coupling, a lot of attempts have been tried to improve the isolation between ports in MIMO antenna. A slotted patch MIMO antenna at 3.5 and 5.5 GHz is reported in [3].The MIMO antenna offersmore than 14 dB mutual coupling on both bands [3].The Dual band MIMO Antenna using slotted loaded techniques has been presented.The antenna has mutual coupling of 29 dB at 2.4 GHz and 24 dB at 3.4 GHz. A compact dual band MIMO antenna at 2.8 and 5.2 GHz is reported in [5].The MIMO antenna offers more than 12 dB mutual coupling on both bands.The Dual band MIMO Antenna design at 2.4 GHz and 5.5 GHz has been presented [6]. The antenna has mutual coupling of 21 dB at 2.4 GHz and 18 dB at 5.5 GHz.

The dual band monopole MIMO antenna operated at 2.5 GHz and 5.5 GHz and more than 15 dB mutual coupling on both bands reported in [7]. A simple compact fractal based MIMO antenna has been reported in [8]. The MIMO antenna have mutual coupling of 25 dB at 2.4 GHz.A compact MIMO antenna for 4G and 5G application has been reported in [9].This antenna having more than 15 dB isolation.But all reported antenna [4-8] having low mutual coupling and low gain which has been taken as an objective for this research work.

In this paper, a compact dual-band MIMO antenna is proposed. The antenna has been design at3.7 GHz and 4.9GHz to operate 5G mobile band (n77/78).The MIMO antenna offers very high mutual couplingof 48dB at 3.7 GHz and 38 dB at 4.9GHz over the entire operatingband. The maximum peak gain of MIMO antenna is 4.3 dBi.

II. DESIGN IMPLEMENTATION AND GEOMETRY FOR PROPOSED ANTENNA

2.1 DUAL-BAND DESIGN

The dimensions and geometry of the single band patch antenna is shown in Fig. 1. The single band MIMO antenna has been design on FR4 Substrate with εr=4.4 and height is 1.6mm.The rectangular patch is operated at high freq 4.9 GHz.The overall substrate size of antenna is 28 x 30 mm^2.The length of patch is 13mm and width is 19mm.The resonating length of patch antenna is calculated by equation [1].

$$L_1 = \frac{\lambda}{2\sqrt{\varepsilon_r}} \qquad (1)$$

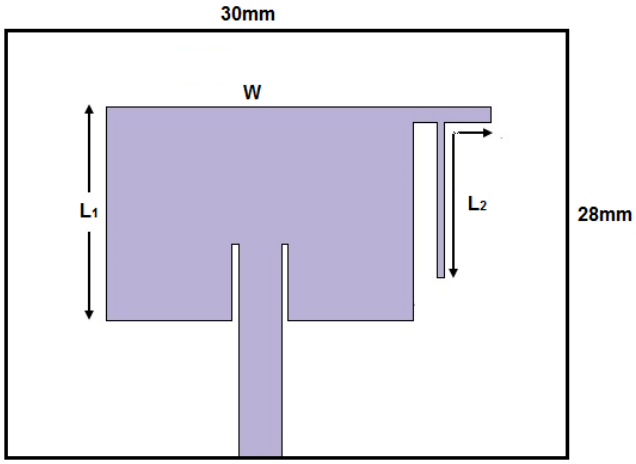


Fig. 1 Dual band antenna Configuration

The second resonating frequency of patch antenna is tuned by t stub radiating element and calculated by equation [2].

$$L_2 = \frac{\lambda}{4\sqrt{\varepsilon_r}} \qquad (2)$$

2.2 DUAL BAND MIMO DESIGN

Fig. 2 depicts the geometrical configuration of the proposed dual band MIMO antenna. The MIMO antenna is constructed of a FR4 substrate with a εr = 4.4 and a height of 1.6mm. The overall substrate dimension is 28 x 68 mm^2. The antenna is fed with 50 ohm microstrip feed line. The T-stub loaded element connecting to the radiating patch can be adjusted to create a dual-band antenna that can function in both required frequency bands. The following are the final physical dimensions for the best result.

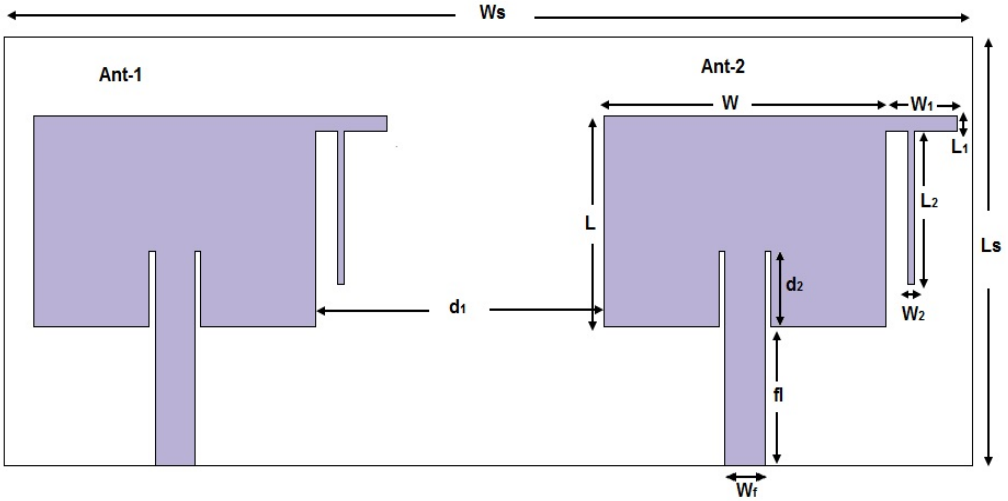


Fig.2 Geometry of the Proposed Dual band MIMO antenna

Table 1: Physical dimension

Parameters	Value (mm)	Parameters	Value (mm)
L	13.0	Ls	28.0
W	19.0	Ws	68.0
L1	1.0	W1	5.0
L2	10.0	W2	0.5
Wf	2.8	d2	5.0
Fl	9.2	d1	20.0

3. RESULTS AND DISCUSSION FOR PROPOSED ANTENNA DESIGN

In this section, the simulated results of MIMO antenna design are presented. The HFSS software being used for antenna design and simulation. Below is a plot of the optimised Dual band MIMO antenna characteristics. The MIMO antenna operating resonance frequencies are 3.7 GHz and 4.9 GHz.

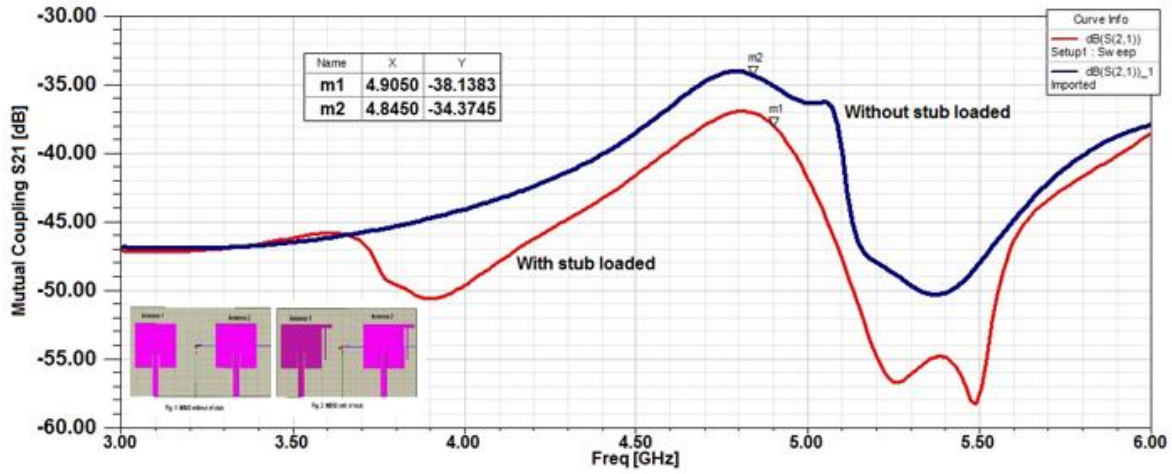


Fig.3Mutual Coupling S21 of MIMO antenna with & without Tstubloaded

In Fig.3 shows S21of MIMO without and with stub loaded antenna. It can be seen that MIMO antenna without stub loaded has mutual coupling is34 dBand MIMO antenna with stub loaded has mutual coupling is 38 dBataround 4.9 GHz. This is indicate that significant improvement in mutual coupling S21 in MIMO with T stub loaded structure.

Table 2: Comparison table of MIMO Antenna

Sr. No.	**Results**	**Freq [GHz]**	**Return loss [dB]**	**VSWR**	**Bandwidth [MHz]**	**Gain [dB]**	**Mutual coupling S21 [dB]**
1.	Without Stub loaded MIMO	4.87	-23.19	1.14	200	4.2	-34.3
2.	With Stub loaded MIMO	3.76	-17.00	1.32	60	2.1	-38.1
		4.92	-35.02	1.03	200	4.3	-49.1

Table 2it can conclude that the metallic stub loaded element are introduced in the patch radiating element of the proposed MIMO antenna to produce high isolation and dual band characteristics.

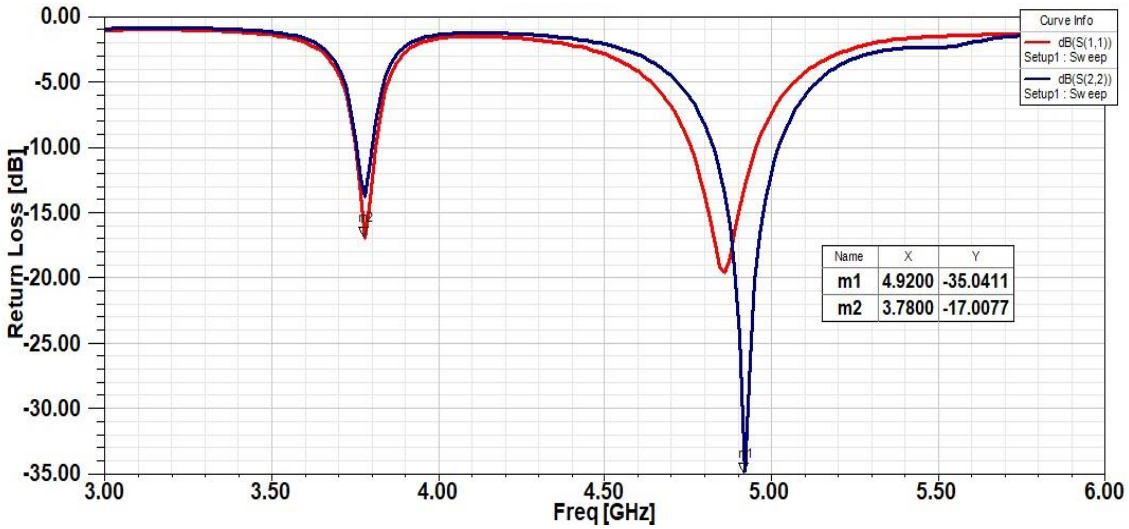


Fig.4 S-Parameters of Dual band MIMO antenna

The S11 and S22 of a dual band MIMO antenna are shown in Fig. 4, and the Return Loss value is -17.00 dB at 3.78 GHz and -35.04 dB at 4.92 GHz respectively. The optimal return loss is roughly -10 dB, which means that 90% of the power is transferred to the source and 10% is reflected back to the load.

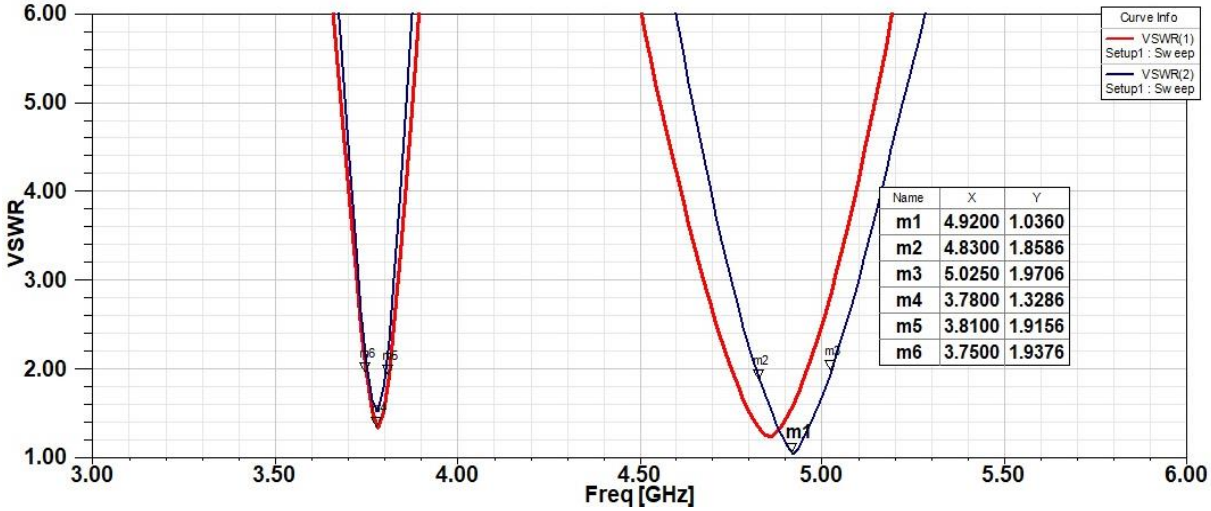


Fig.5VSWR of Dual band MIMO antenna

The VSWR of the proposed dual band MIMO antenna is shown in Fig. 5, and it can be concluded that the VSWR value is 1.32 at 3.78 GHz and 1.03 at 4.92 GHz. The suggested dual band MIMO antenna has a bandwidth of 60 MHz at 3.7 GHz and 200 MHz at 4.9 GHz which is outstanding.

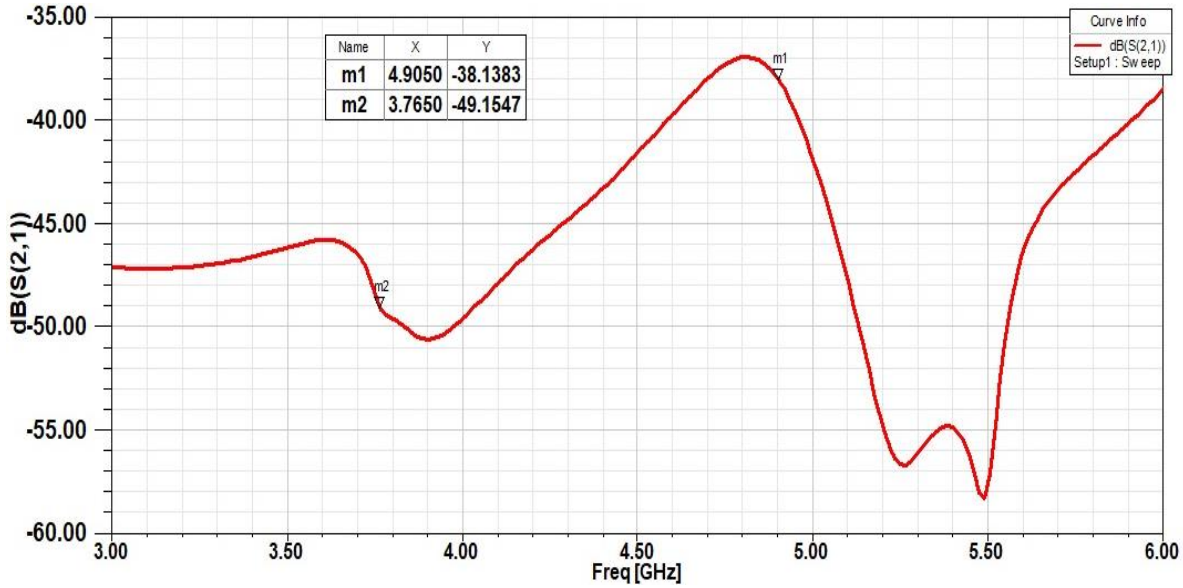
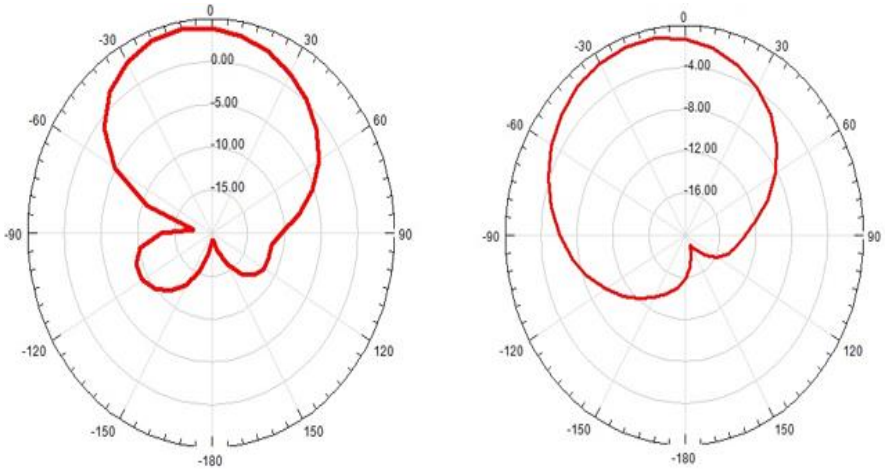


Fig.6: Mutual Coupling (S21) of Dual Band MIMO antenna

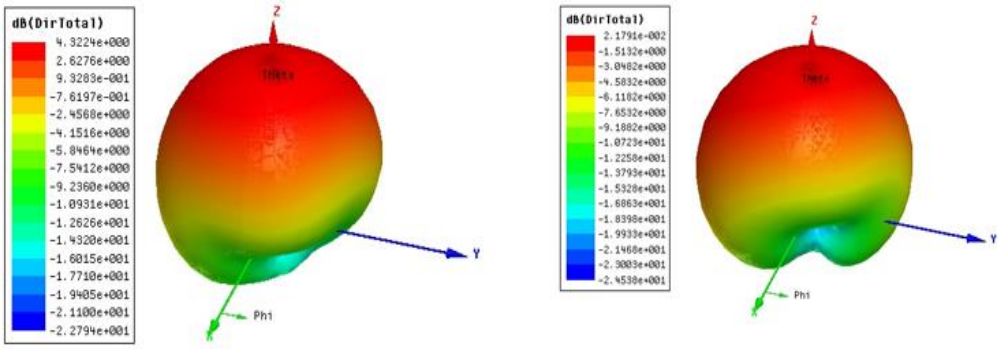
The mutual coupling of a dual band MIMO antenna is shown in Fig. 6, where the Mutual Coupling S21 value is -49.15 at 3.76 GHz and -38.13 at 4.92 GHz.The proposed MIMO antenna has very high mutual coupling on both bands.



(a) 4.9 GHz (b) 3.7 GHz

Fig.7 Radiation pattern of Dual band MIMO antenna

Fig.7shows the radiation pattern of the of Dual band MIMO antenna, it conclude that both operating frequency band radiation pattern is stable.



(a) 4.9 GHz (b) 3.7 GHz

Fig.8Gain of Dual band MIMO antenna

The Gain of proposed dual band MIMO antenna is 2.1 dB at 3.7GHz and4.3 dB at 4.9 GHz.

Table 3 : Performance comparison of the proposed dual band MIMO with reference antennas

Ref.	**Size [mm^2]**	**Freq [GHz]**	**Mutual Coupling S21 [dB]**	**Gain [dB]**	**Mutual coupling Techniques Used**
Ref [4]	60 x 70	2.4 /3.4	29 / 24	1.8	Slot loading
Ref [5]	38 x 43	2.7 /5.3	12 / 15	2.0	Defected Ground Structure
Ref [6]	50 x 50	2.4 / 5.5	21 / 18	4.1	Defected Ground Structure
Ref [7]	33 x 44	2.5 /5.5	15 / 20	2.0	T-shape stub element
Ref [8]	38 x 96	2.4	25	4.0	mushroom-shaped EBG
Proposed Work	28 x 68	3.7/4.9	48 / 38	4.3	Stub loaded patch

In comparison to [4-8], it shows that the proposed dual band MIMO antenna has a relatively high mutual coupling. The MIMO antenna has a maximum gain of 4.3 dBi.

III. CONCLUSION

For 5G mobile applications, a compact dual-band MIMO antenna has been developed. The antenna's overall dimensions are 28 x 68 x 1.6 mm^3 with a relatively small size. A rectangular patch radiator with T-stub loaded element make up the proposed dual band MIMO antenna. The metallic stub loaded element is used to create a dual band characteristics with better mutual coupling between the elements. On both bands, the proposed dual band MIMO antenna has an extremely low mutual coupling of (S21<37 dB). The suggested antenna supports the 3.7 GHz (n77) and 4.9 GHz(n88) bands for 5G applications. At 3.7GHz and 4.9GHz, the antenna offers bandwidth of 60 MHz and 200 MHz. This dual band MIMO antenna is appropriate for 5G mobile communications.

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