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Design and Analysis of MIMO Dual Band Patch Antenna for 5G New Radio Applications in Mobile Terminals

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Abstract: *This paper presents a dual-band monopole antenna design with compact size for 5G communication under 6 GHz band frequency. The metallic monopole stub structure is used for miniaturization of antenna. It has a compact size of 24 mm × 14 mm × 1.6 mm^3. The suggested antenna has been design on FR4 material with εr = 4.4 with 1.6 thickness. The L-shape monopole antenna is modified by adding semi-circular element in radiating structure of monopole to obtain dual-band resonance. The proposed antenna has 5G application in the bands of 2.5 GHz (2.34 GHz-2.62 GHz) and 3.6 GHz (3.20 GHz-5.20 GHz). The bandwidth of antenna getting 280MHz and 2300MHz at 2.5GHz and 3.6GHz respectively. VSWR is less than 1.06 for both the bands. The designed dual band monopole antenna covers 5G bands of 2.3-2.4GHz (n30/n40), 2.4-2.5GHz (n7/n38/n41/n90), and 3.2-5.2GHz (n77/n78/n80). This proposed dual band monopole antenna is suitable for 5G Communications.*

Index Terms - Monopole, Dual-band, Miniaturization, 5G and L shape.

I. Introduction

The fifth generation (5G) communication has been widely discussed to provide high data-rate communications in the future. The design and testing of the 5G communication system huge on the understanding of the propagation channels [1], and a large body of channel measurements is thus required. Currently, 5G mobile systems are broadening their spectrum to support a high data rate. In the World Radio Communication Conference (WRC) in 2015, the 5G candidate frequency bands below 6 GHz have been widely discussed, and the following frequency ranges have been suggested: 470–694, 2300–2700, 3300–3800, and 4500–4990 MHz Among them, 2.5 GHz & 3.5 GHz has been widely considered, as it can be accepted for most of countries. Therefore this paper was focused on the propagation channel characterizations at 2.5/3.5 GHz bands. Previously, 2.5/3.5 GHz propagation channel has been studied mainly for the Wireless applications with limited bandwidth & large size [2-4] or the Broadband Fixed Wireless Access [5-6]. Few works has been conducted for the 5G wireless propagation channels.

A compact dual-band antenna is designed for 4.5GHz and 7.8GHz 5G and C-band applications and the antenna satisfied the -10dB impedance bandwidth is 64MHz (4.468GHz4.532GHz) and 128MHz (7.736GHz-7.864GHz) [7]. Dual-band miniaturized planar inverted F-antenna is designed for WLAN and 5G applications which has been designed to operate in the WLAN (2.4GHz), Bluetooth (2.4GHz), LTE2500 (2.5GHz) and 5G communication (4.5GHz) [8]. Single band elliptical Microstrip patch antenna is designed at 3.5GHz for 5G with impedance bandwidth around 700MHz and size is 48 x 26 mm [9]. Rectangular Patch antenna at 4.5GHz for 5G with impedance bandwidth around 700MHz and size is 50 x 40 mm presented [10].But all this antenna having low bandwidth and large size so with the improved bandwidth & compactness which has been taken as an objective for this research work.

In this paper, a compact dual-band monopole antenna is proposed. In presented antenna, two frequency bands has been covered 2.5 GHz and 3.5 GHz. A compact dual-band antenna with excellent impedance bandwidth is proposed.

II. Antenna Configuration

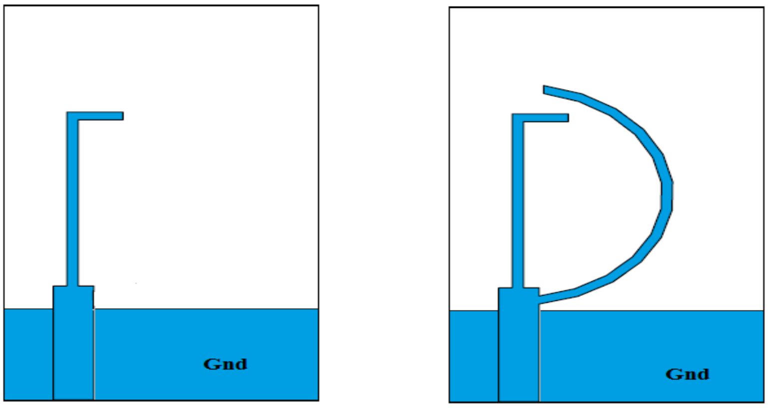
The dimensions and geometry of the proposed dual band monopole antenna is shown in Fig. 2. The radiating L-shape element has been printed on top side of FR4 Substrate with εr=4.4 and thickness (h) is 1.6mm. Partial ground plane is used to obtain the desired bandwidth and radiation response. Antenna-1 (as shown in Fig.1.a) is optimized to operate at frequency 3.5 GHz. The Antenna-1 structure incorporates L-shaped radiating monopole connected to the 50 Ω feed-line. The total length of the monopole (L=L1+L2) is calculated using Eq. (1),

$$L = \frac{C}{4f_1\sqrt{\varepsilon_{reff}}} \qquad (1)$$

The Antenna-2 is developed to function at a second operating frequency of 2.5 GHz. This antenna comprises a semi-circular radiating monopole connected to a 50 Ω feed-line (as shown in Fig. 1.b). The radiating semi-circular arc radius is estimated by Eq. (2) where C represents the circumference of the semi-circular and Calculated by Eq. (3)

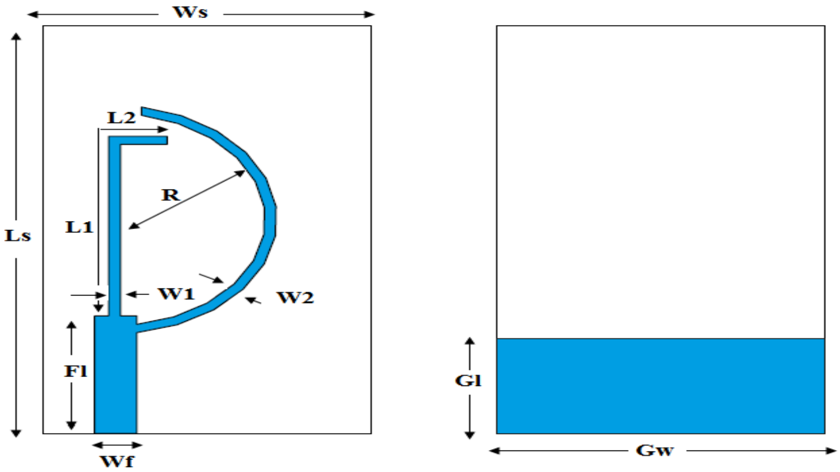
$$C = \pi R \qquad (2)$$

$$C = \frac{C}{(4f_2\sqrt{\varepsilon_{reff}})} \qquad (3)$$



(a) Antenna 1 (b) Antenna 2

Figure 1. Antenna Evolution Steps



(a) Top View (b) Side View

Figure 2. Geometry of the proposed dual band monopole antenna.

Parameters	Dimensions (mm)	Parameters	Dimensions (mm)
L1	11.0	Ls	24.0
W1	0.5	Ws	14.0
L2	2.5	W2	0.5
R	6.0	Wf	1.8
Gw	14.0	Gl	6.0
Fl	7.2		

Table 1: Optimized Parameter Values

III. Results And Discussion

The proposed dual monopole antenna has been design using HFSS software. The simulated return loss of Antenna-1 and Antenna-2 designs is shown in Figure 3. Antenna 1 is getting single frequency at 3.50 GHz and Antenna 2 is getting dual band 3.50GHz and 2.50GHz.The excellent impedance matching observed on both bands.

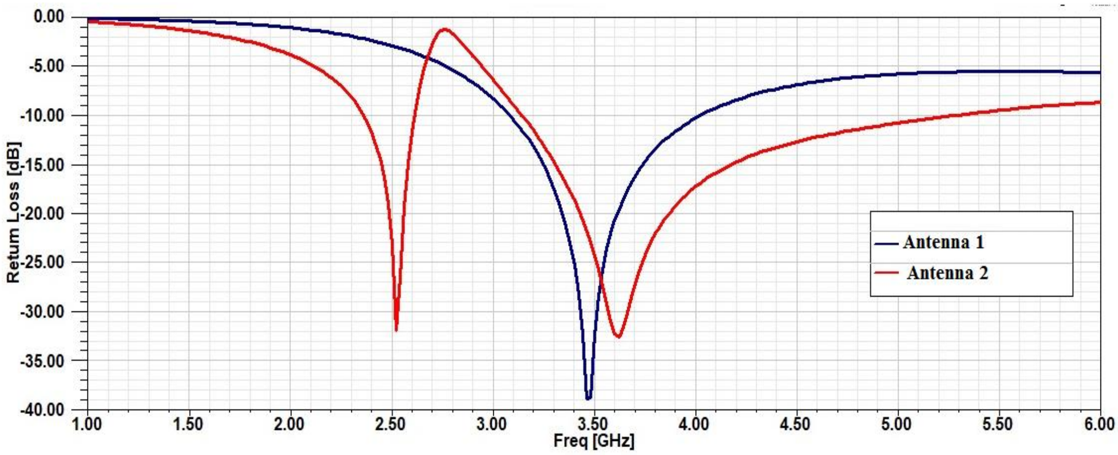


Figure 3: Simulated return loss of antenna evaluation step

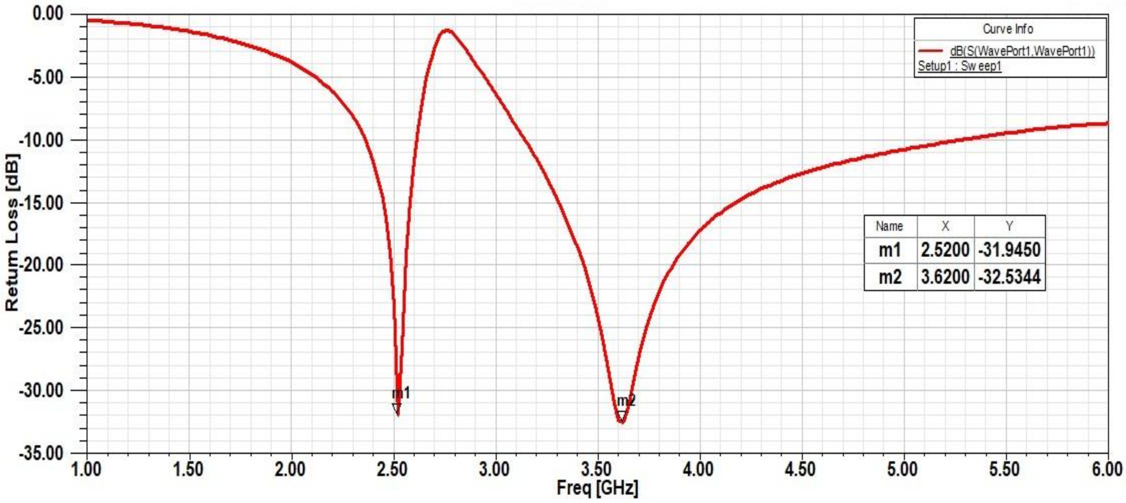


Figure 4: Simulated Return Loss of proposed dual band monopole antenna

Fig.4 shows the Simulated Return Loss of proposed dual band antenna it can conclude that Return Loss value is -31.94 at 2.52GHz and is -32.53 at 3.62GHz.

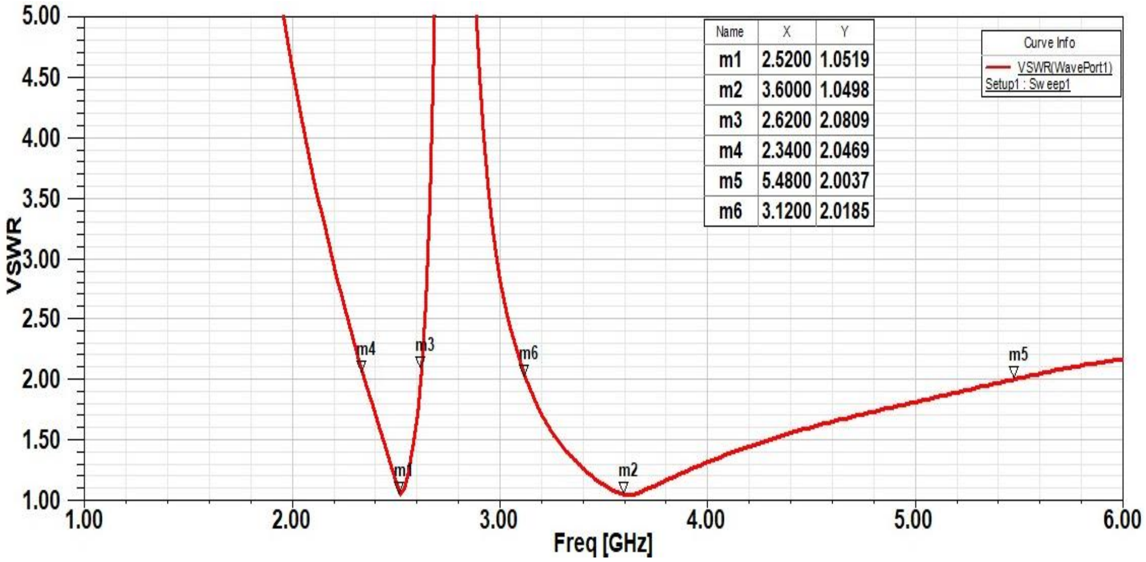
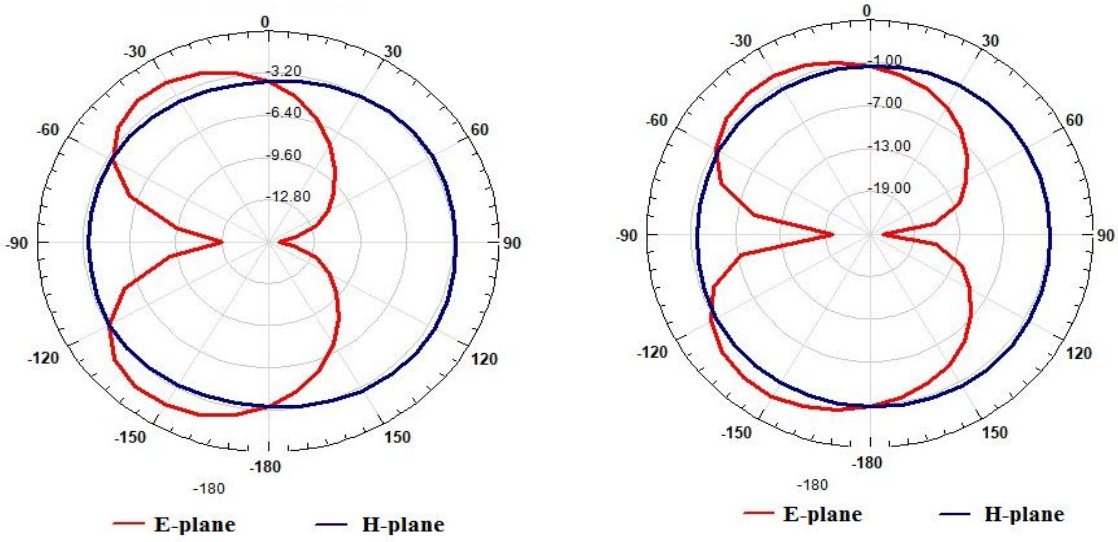


Figure 5: Simulated VSWR of proposed dual band monopole antenna

Fig.5 shows the Simulated VSWR of proposed dual band antenna.It can be concluded that VSWR value is 1.05 at 2.5GHz and is 1.04 at 3.6GHz. The proposed antenna offers excellent bandwidth of 280MHz at 2.5GHz and 2300MHz at 3.5GHz.



(a) 2.40 GHz (b) 3.60 GHz

Figure 6: Simulated Radiation Pattern of proposed dual band monopole antenna

Figure 6(a)-(b) shows the Radiation pattern of proposed dual band antenna at 2.45 GHz and 3.60 GHz .It conclude that Radiation pattern is bidirectional in E-plane and Omni-directional in H-plane.

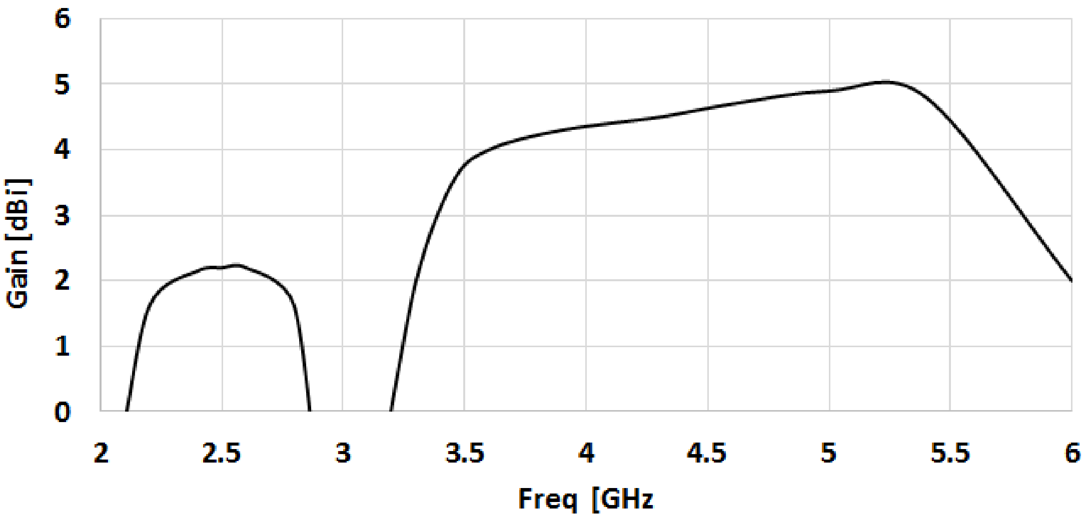


Figure 7. Simulated average gain of the proposed dual band monopole antenna

The proposed antenna has a peak gain of 2.2dBi at 2.5 GHz, and 4.2dBi at 3.6 GHz frequency band.

IV. Conclusion

A compact dual-band monopole antenna is presented for 5G applications. The overall size of antenna is very small 24×14×1.6 mm^3. In design steps of dual-band antenna, simple L-shape monopole for 3.6 GHz is designed and then adding half semi-circle strip in radiating monopole patch structure to obtain dual-band band resonance. The frequency and bandwidths of the bands can be adjusted by tuning the lengths of the attached L-strip & semi circle of monopole. Radiation pattern is stable with both dual frequency bands and maximum gain of 4.2 dBi is obtained.

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