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SUB-6 GHZ AND MILLIMETER-WAVE ANTENNA FOR FIFTH GENERATION MOBILE COMMUNICATION SERVICES

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Abstract: This paper presents a dual-band, sub-6GHz, and millimeter-wave antenna for fifth-generation mobile communication devices. This antenna works on sub-6 GHz and millimeter-wave frequency band with one center frequency as 3.6 GHz and a wideband in millimeter-wave range. This prototype is designed on an FR-4 substrate of a thickness of 1.6 mm. The simulations are performed on CST. It offers a bandwidth of 700 MHz and gain of 1.5 dBi in the sub-6 GHz band and 15 GHz bandwidth in the mm-wave band with a gain of more than 3.5 dBi. The radiation efficiency of more than 75% in the sub-6 GHz band and more than 55% for the mm-wave band. Both operating bands can be controlled independently.
Keywords: 5G, FR-4, Sub-6 GHz, Millimeter-wave, Dual-band

1. INTRODUCTION

Antennas are essential devices for any wireless communication and researches is going on for increasing the speed of wireless communication. 5G standards are proposed with two operating bands, one sub-6 GHz band, and an mm-wave band. Getting both bands on the same device and the same chip or substrate is the task for the future and the work proposed in this paper is based on the same challenge.

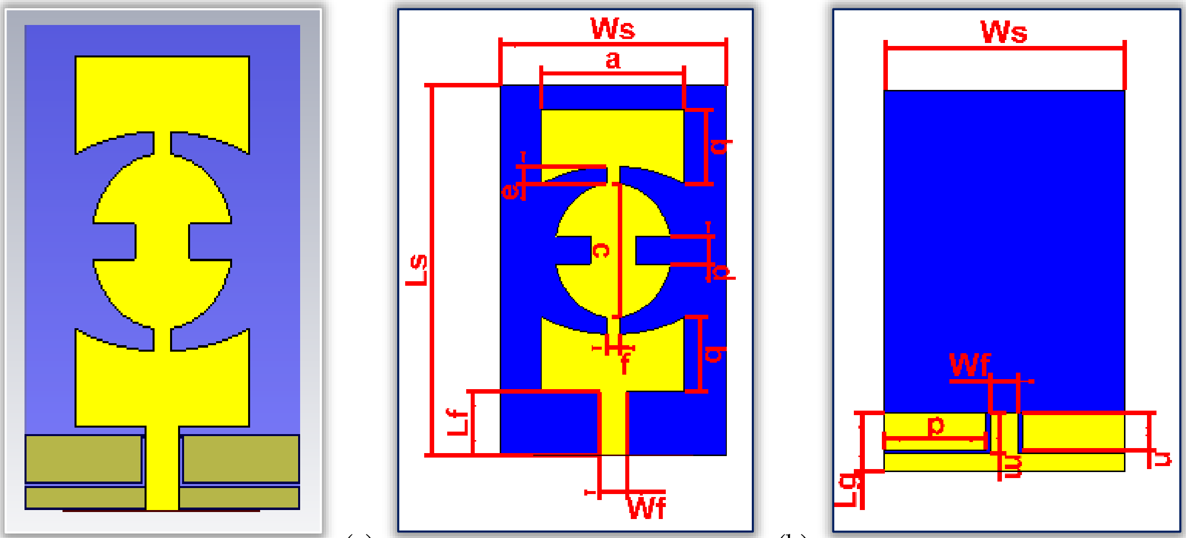
A MIMO antenna system for the fourth generation and fifth generation applications is designed to work at 2.1 GHz and 12.5 GHz frequency is fabricated RO-4350 substrate. DGS is used to improve isolation and MIMO port efficiency.[1] A MIMO 8X8 antenna operating at 15 GHz for 5G communication is prepared on Duroid Rogers 5880 substrate. The author claims to achieve high gain and high isolation for both indoor and outdoor access.[2] An eight-antenna MIMO antenna array operating 4G band (2.496-2.69 GHz) and 5G band (3.3-3.7 GHz) for metal-framed mobile phone is presented. The total efficiency of 50% to 60% and gains from 1.2 to 2.5 dBi is obtained.[3] A hybrid MIMO antenna for 4G/5G multi-mode smartphone applications are discussed by the author that covers GSM850/900/1800/1900, UMTS2100, LTE2300/2500, and 5G band from 3400–3600 MHz with antenna efficiency, gain, and ECC meeting the requirements of MIMO systems.[4] A compact 3D meandered loop antenna for WWAN/LTE mobile applications with seven resonant frequencies is presented. The loop itself is responsible for generating four resonant frequencies and the other three are generated by three parasitic elements that are placed in proximity of the meandered loop. The measurements are done after placing the antenna system in the mobile case, which makes the results more practical.[5] A reconfigurable antenna incorporating a Digitally Tunable Capacitor (DTC) for resonating over an extended range of frequency band including PCS, UMTS, 4G, and 3.5GHz band of 5G communication system.[6] A 2 × 2 planar MIMO antenna system is proposed whose resonant frequency ranges from 2GHz to 12GHz, i.e. ultra-wideband (fractional bandwidth=143.2%) with maximum measured gain value of 4.8 dB.[7][8] A four port slot antenna is presented in the article that also operates in the sub-6 GHz band for the 5G communication systems. [10]

Both operating frequencies are very different, and the gap between the two frequencies is huge. Getting an antenna to operate on both frequencies can solve many challenges of future 5G technology. The analysis on both frequencies in a single simulation takes a lot of time, memory and the same boundary definition will not provide proper results. So, a single simulation for the complete band from 0 to 40 4GHz is done and then separate simulation on sub-bands from 2 to 5 GHz and 14 to 36 GHz. The results show that the antenna works on both proposed bands of 5G technology.

2. ANTENNA DESIGN

This antenna is inspired by the antenna in [9], which is a UWB antenna with defected ground structure. Figure 1 (a) shows the transparent model of the antenna in which both top and bottom layers are visible. Figure 1(b) shows the top layer on the antenna that has the antenna patch and the feed line. The dimensions are marked and the optimized values are given in Table I. Figure 1(c) depicts the bottom layer of the antenna with the defected ground structure. IT has two L slots to generate UWB characteristics and the patch is responsible for the 3.6 GHz operating frequency band.

The E shape is cut out from the patch to increase the electrical length of the antenna so that the same antenna can resonate in the sub-6 GHz band of the 5G communication systems. The antenna is proposed on FR-4 substrate, which is very effective and readily available. The antenna is fed with 50-ohm microstrip transmission line and the simulations were carried out using CST Microwave Studio.



(a) (b) (c)

Figure 1: The proposed antenna, (a) Transparent View (b) Front-View (c) Back-View

Table 1: Design Parameters

Parameter	Value (mm)	Parameter	Value (mm)	Parameter	Value (mm)	Parameter	Value (mm)
a	8.5	e	1	n	2.1	Lf	3.8
b	4.45	f	0.8	p	5.75	Ws	13.5
c	7.95	Lg	3.4	Ls	22	H	1.6
d	1.6	m	2.3	Wf	1.6		

3. RESULTS AND DISCUSSION

Figure 2 shows the s-parameter for the antenna, in which one can observe that the antenna operates at 3.6 GHz band, 5.7 GHz, wide-band from 18 to GHz band, and at 38 GHz band. Figure 3(a) and figure 3(b) shows the s-parameter for the sub-6 GHz band, and mm-wave band separately. Around 700 MHz 10 dB bandwidth in sub-6 GHz band and 15 GHz bandwidth in the mm-wave band is available.

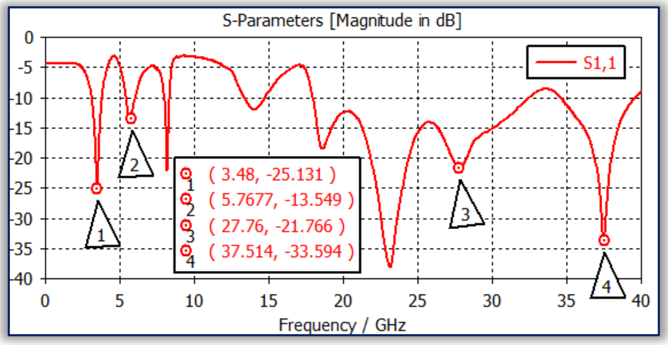
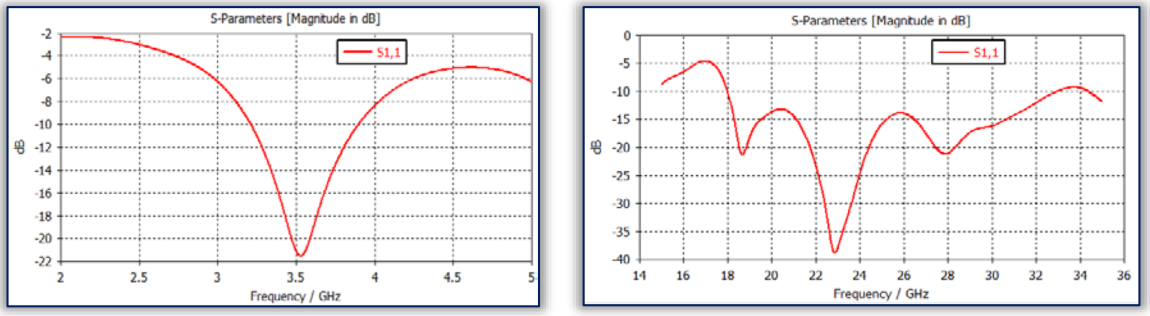


Figure 2: S-Parameter of the Proposed Antenna (0 to 40 GHz)



(a) (b)

Figure 3: S-Parameter of the Proposed Antenna (a) Sub-6 GHz band (b mm-wave band

Figure 4 shows the radiation efficiency of the proposed antenna and more than 75% radiation efficiency is achieved at 3.6 GHz and around 60% radiation is observed at 28 GHz frequency. Although the s-parameter for 5.5 GHz and 38 GHz, less than -10 dB but the radiation efficiency is below 50% so it is not appropriate to consider it as the operation band of the antenna.

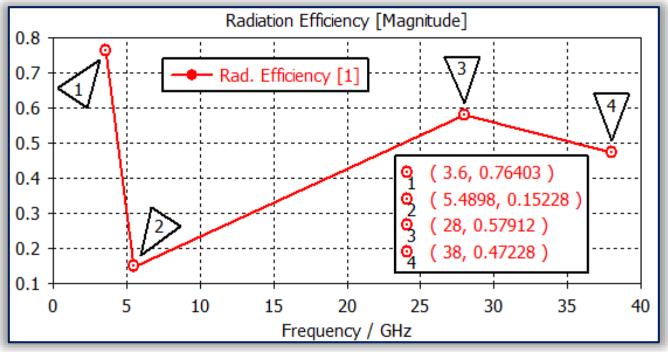
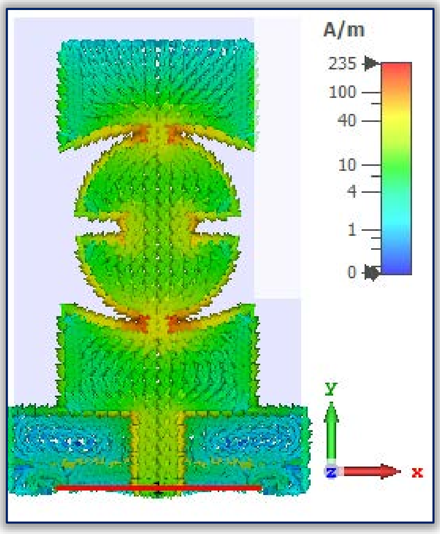


Figure 4: Radiation efficiency v/s Frequency



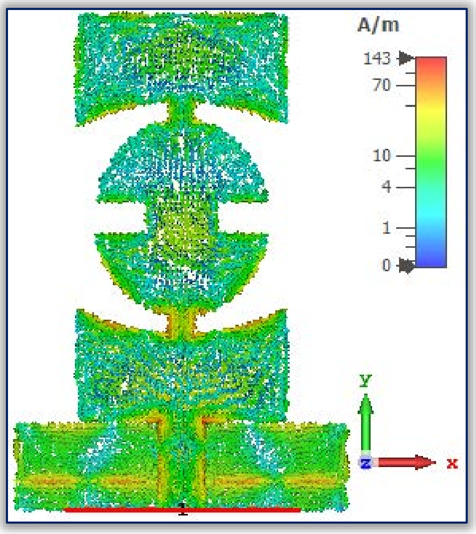
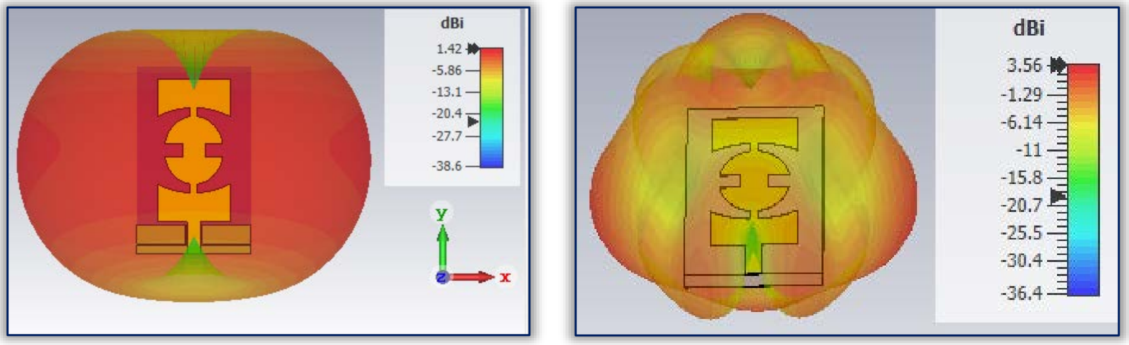


Figure 5: Surface Current at 3.6 GHz Figure 6: Surface Current at 5.5 GHz

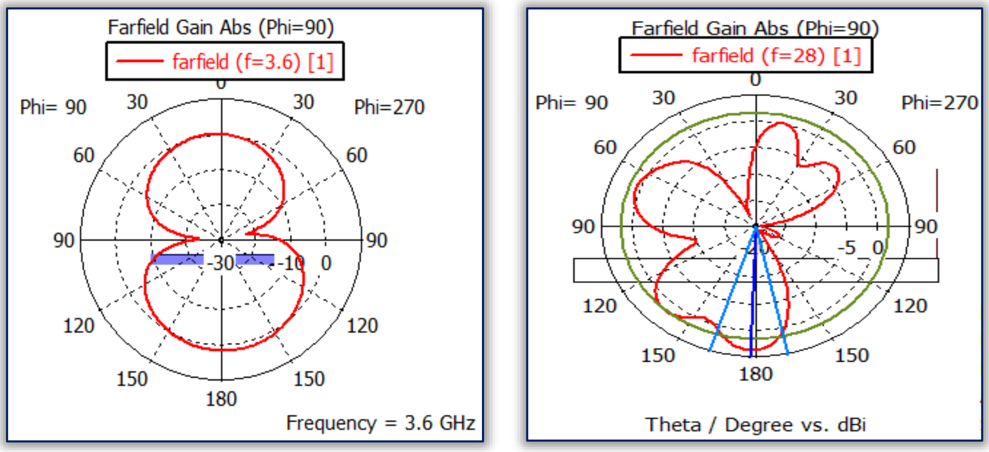
(a)



(b)

Figure 7: 3D Antenna Radiation Pattern for antenna 1 (a) At 3.6 GHz (b) At 5.5 GHz

(a)



(b)

Figure 8: 2D Antenna Radiation Pattern for antenna 1 (a) At 3.6 GHz (b) At 5.5 GHz

The surface current distribution of the antenna for 3.6 GHz and 28 GHz is shown in Figure 5 and Figure 6 respectively. At 3.6 GHz, the high current density is observed around the patch, so it is validated that the patch is responsible for antenna radiation at 3.6 GHz. From figure 6, it is observed that the L slots in the ground plane are having a high current density at 28 GHz around 143 A/m. So the same antenna radiates at 3.6 GHz and at 28 GHz.

Figure 7 (a) and (b) shows the 3D radiation pattern at 3.6 GHz and 28 GHz and the obtained gain is 1.42 dB and 3.56 dB respectively. Figure 8 (a) and (b) shows the polar plot of the antenna at 3.6 GHz. It is evident that the radiation pattern forms a figure of eight.

4. CONCLUSION

In this paper, a dual-band, sub-6GHz, and millimeter-wave antenna for fifth-generation mobile communication devices. This antenna works on sub-6 GHz and millimeter-wave frequency band with one center frequency as 3.6 GHz and a wideband in millimeter-wave range. This prototype is designed on an FR-4 substrate of a thickness of 1.6 mm. The simulations are performed on CST. It offers a bandwidth of 700 MHz and a gain of 1.5 dBi in the sub-6 GHz band and 15 GHz bandwidth in the mm-wave band with a gain of more than 3.5 dBi. The radiation efficiency of more than 75% in the sub-6 GHz band and more than 55% for the mm-wave band. Both operating bands can be controlled independently. The proposed antenna can be a good candidate to be installed in future I-pads and wi-fi devices or portable wi-fi routers.

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References

[1] M. Ikram, R. Hussain, and M. S. Sharawi, "4G/5G antenna system with dual function planar connected array," IET Microwaves, Antennas Propag., vol. 11, no. 12, pp. 1760–1764, Sep. 2017.

[2] A. S. Ruswanditya, Y. Wahyu, and H. Wijanto, "MIMO 8×8 antenna with two H-slotted rectangular patch array for 5G access radio at 15 GHz," in 2017 International Conference on Control, Electronics, Renewable Energy and Communications (ICCREC), 2017, vol. 2017-Janua, pp. 221–226.

[3] H. Zou, Y. Li, B. Xu, Y. Luo, M. Wang, and G. Yang, "A dual-band eight-antenna multi-input multi-output array for 5G metal-framed smartphones," Int. J. RF Microw. Comput. Eng., vol. 29, no. 7, p. e21745, Jul. 2019.

[4] Y. Ban, C. Li, C. Sim, G. Wu, and K.-L. Wong, "4G/5G Multiple Antennas for Future Multi-Mode Smartphone Applications," IEEE Access, vol. 4, no. c, pp. 2981–2988, 2016.

[5] D. Wu, S. W. Cheung, and T. I. Yuk, "Compact 3D-loop antenna with bandwidth enhancement for WWAN/LTE mobile-phones applications," IET Microwaves, Antennas Propag., vol. 11, no. 2, pp. 240–246, 2016.

[6] L. H. Trinh, F. Ferrero, L. Lizzi, R. Staraj, and J.-M. Ribero, "Reconfigurable Antenna for Future Spectrum Reallocations in 5G Communications," IEEE Antennas Wirel. Propag. Lett., vol. 15, no. c, pp. 1297–1300, 2016.

[7] H. AL-Saif, M. Usman, M. T. Chughtai, and J. Nasir, "Compact Ultra-Wide Band MIMO Antenna System for Lower 5G Bands," Wireless Communications and Mobile Computing, vol. 2018, pp. 1–6, 2018.

[8] H. Alsaif, M. Usman, M. T. Chughtai, and J. Nasir, "CROSS POLARIZED 2×2 UWB-MIMO ANTENNA SYSTEM FOR 5G WIRELESS APPLICATIONS," Prog. Electromagn. Res. M, vol. 76, no. October, pp. 157–166, 2018.

[9] J. R. Panda and R. S. Kshetrimayum, "A compact 3.5/5.5 GHz dual band-notched monopole antenna for application in UWB communication systems with defected ground structure," in 2010 Indian Antenna Week: A Workshop on Advanced Antenna Technology, 2010, pp. 1–7.

[10] A. Agarwal and J. Vaswani, "A four port, dual band antenna for fifth generation mobile communication and WLAN services," ACTA Tech. CORVINIENSIS – Bull. Eng., vol. 4, no. XIII, pp. 73–76, 2020

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