A Miniaturized Dual-Band Antenna for 5G mm-Wave Applications

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***Abstract*—This research introduces a compact microstrip antenna with dual-band capabilities, characterized by its broad bandwidth. The antenna configuration involves adjustments to the ground plane, enabling it to operate efficiently in two frequency bands. The proposed antenna operational bandwidth encompasses both the 28 and 38 GHz bands, making it suitable for millimeter wave applications within the context of 5G technology, while maintains a compact structure with dimensions of 5 x 9.2 mm^2. The proposed design is mounted on Roger's RT5880 laminated substrate, which has a thickness of 0.787 mm. The reduction of ground length leads to a widened bandwidth, spanning from 24.8-28.7 GHz at lower band, and from 36.2-40.8 GHz at higher band.**

***Index Terms*—Wideband, mm-wave antenna, Miniaturized, 5G**

I. Introduction

Over the past few years, there has been a growing focus on the antennas used in fifth-generation (5G) wireless communication. The millimeter-wave (mmW) antenna system holds significant importance within 5G communication, as it offers high-speed data transmission and minimal latency. The advancement of 5G technology is primarily driven by its ability to accommodate a substantial user base while delivering impressive data rates [1], [2]. The advancement in communication technology has led to an increased utilization of wireless devices. Furthermore, there is a consistent rise in the need to miniaturize these wireless devices, achieve faster data rates, and increase their operational speed [3], [4]. However, capitalizing on these advantages requires access to wider frequency bands, particularly the millimeter-wave spectrum, which facilitates congestion relief, improved data rates, and meeting the escalating demands of data-centric applications, smart devices, and the Internet of Things (IoT) within 5G implementation [5].

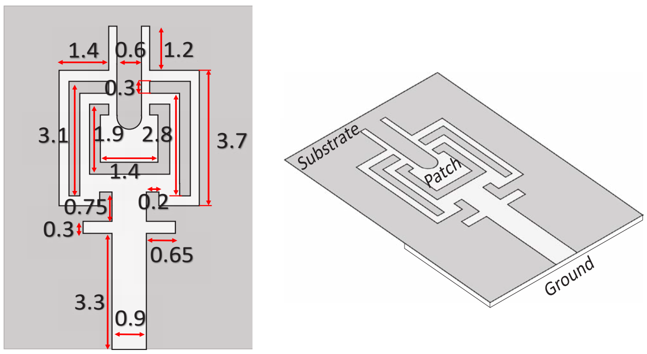
In recent times, significant research in the literature has been focused on developing planar designs for millimeter-wave antennas intended for 5G mobile devices [6]–[8]. In the [9], an antenna operating at 60 GHz is constructed, featuring radiating patch elements adorned with E-shaped slots. The [10] describes a dual-band circular polarized antenna that operates at 28/48 GHz, offering bandwidths of 1.3 and 1 GHz, respectively. Moreover, a metallic tapered slot antenna designed to operate at the frequency band of 24.25 to 28.35 GHz is presented in [11]. Another antenna utilizing a defected ground structure is employed in an attempt to achieve a wider bandwidth [12]. However, it lacks the capability to cover the frequency bands at 28 and 39 GHz. On the other hand, the [13] introduces a quad-band patch antenna that operates across the frequency bands of 28, 45, 51, and 56 GHz. However, the bandwidth within these designated bands is relatively narrower.

This paper introduces a dual-band microstrip patch antenna with wideband capabilities, designed to operates at frequencies of 28 and 38 GHz. The antenna is designed over a Rogers RT5880 substrate with a thickness of 0.787 mm and relative permittivity ε_r= 2.2. A defected ground technique is employed to enhance the bandwidth of the resonator, ensuring coverage of the desired frequency bands.

II. Design Methodology

The single element dual band antenna is analyzed using the Ansys High Frequency Structure Simulator (HFSS). This antenna design is derived from a square patch antenna, and its dimensions are determined by applying transmission line theory [14]. Fig. 1 illustrates both geometries of the proposed antenna with full ground length and half ground length.

A dual-band response is achieved by selecting a low profile monopole antenna. The antenna is designed on an RT5880 "Rogers" substrate, with dimensions of 5 x 9.2 x 0.787 mm^3, featuring a dielectric constant (ε_r) of 2.2 and a loss tangent (tan δ) of 0.0009. The proposed antenna construction begins with the initial design, which is based on a square patch measuring 3.7 mm in both length and width, and it incorporates a complete ground plane. To enhance its performance, a pair of slots is strategically inserted near the connection point of the patch and the feed line. To achieve a dual-band response, the resonator undergoes certain transformations within the patch. Furthermore, the antenna's branches are connected to the 50Ω microstrip line at a precise angle of $90°$, as illustrated in the accompanying Fig. 1(a). Additionally, a modification was performed in the proposed design's ground plane as shown in the Fig. 1(b), where the full ground was reduced to half to achieve a wider band response at the desired frequency bands.



(a) (b)

Fig. 1: Antenna geometry in mm: (a) Front view with full ground length. (b) Isomeric view with half ground length.

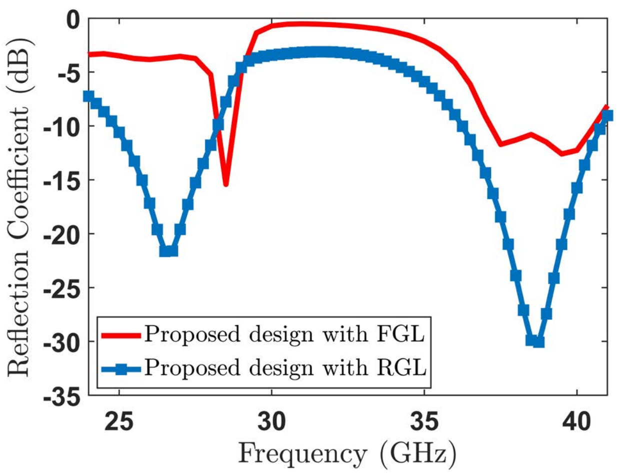
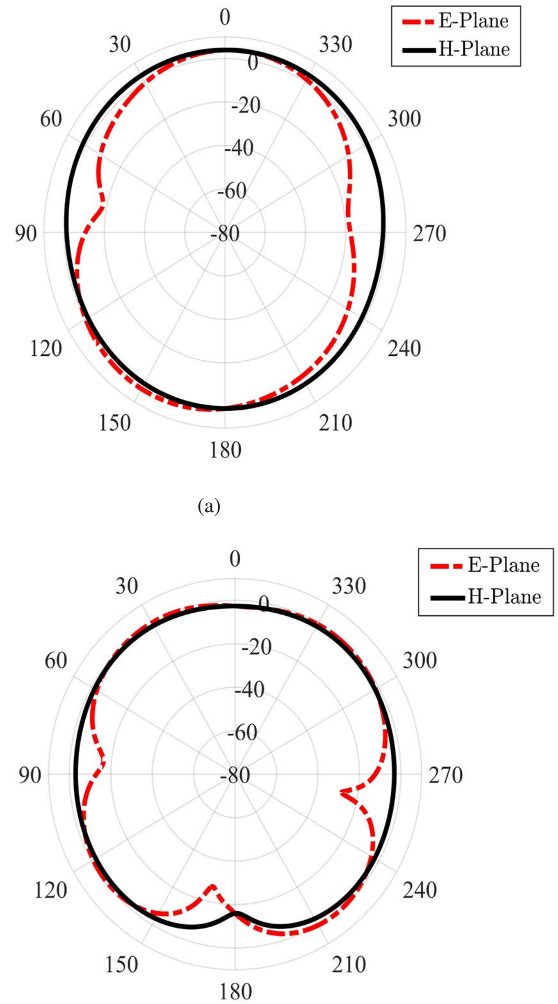


Fig. 2: Reflection coefficient of proposed design with full ground length (FGL) and reduce ground length (RGL).

III. Result and Discussions

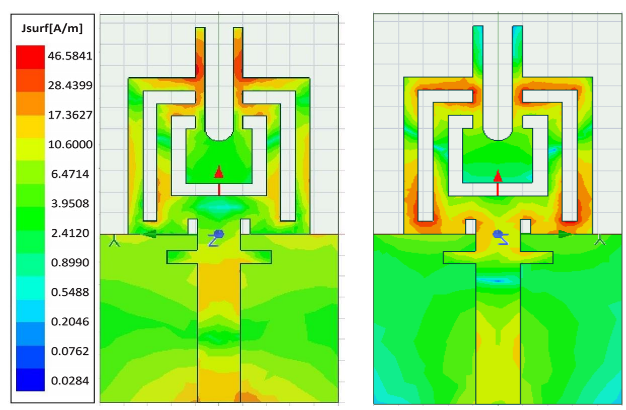
A. S-parameter and Radiation pattern

In the context of the dual-band antenna response presented in this paper, two reflection coefficients (S11) are analyzed. Initially, the S11 for the proposed design, featuring a complete ground, exhibited a narrow bandwidth at the lower frequency band and failed to cover the desired frequency range. However, after reducing the ground length from 9.2 mm to 1.2 mm, the S11 showed significant improvement. This modification resulted in a broader bandwidth, ranging from 24.8 to 28.7 GHz at the lower band and from 36.2 to 40.8 GHz at the higher band, for the proposed dual-band antenna. This effectively covers both desired frequency bands, 28/38 GHz, as illustrated in the Fig. 2. Furthermore, comprehensive simulations were conducted to evaluate its radiation pattern, with simulated radiation patterns generated for both the E-plane and H-plane at 28/38 GHz as depicted in Fig. 3. The results revealed that the radiation pattern responses were predominantly omnidi-



(b)

Fig. 3: Simulated far-field 2-D gain patterns of proposed design (a) 28 GHz (b) 38 GHz



(a) (b)

Fig. 4: Current distribution (a) 28 GHz (b) 38 GHz

TABLE I: Proposed design comparison with recent studies

Ref	Size(mm^3)	Frequency of Operation(GHz)	f1 (Bandwidth)	f2 (Bandwidth)
[15]	20 × 27.5 × 0.254	28 and 38 GHz	27.72 – 28.17 GHz	36.70 – 38.90 GHz
[16]	5.5 x 4 x 0.2	28 and 38 GHz	27.94 – 28.83 GHz	37.97 – 38.96 GHz
[17]	12 x 12 x 0.787	28 GHz	25.2 – 29.4 GHz	-
[18]	18 x 8 x 0.25	28 and 38 GHz	27.7 – 28.3 GHz	37.7–38.3 GHz
Proposed work	9.2 x 5 x 0.787	28 and 38 GHz	24.8 - 28.7 GHz	36.2 - 40.8 GHz

rectional at both 28 and 38 GHz, ensuring consistent signal coverage across a wide range of angles.

B. Current distribution

The current distribution maps at both 28 and 38 GHz provided valuable insights into how electromagnetic energy is distributed within the proposed antenna. Fig. 4 revealed the points of maximum and minimum current intensity along the antenna's elements, shedding light on the resonance behavior and impedance matching of the antenna at these frequencies.

IV. Comparison

Table 1 provides a comparison between the proposed dual-band antenna and recently developed state-of-the-art dual-band operating designs. The comparison considered various performance parameters, such as size and bandwidths.

V. Conclusion

In this paper, we investigate a miniaturized dual-band antenna operating at 28/38 GHz, designed to meet the demands of advanced 5G networks. We explore two ground geometries: full-length and half-length. With a full-length ground, the antenna has narrow bandwidths at both frequency bands. However, by reducing the ground length, the antenna achieves a significantly wider bandwidth, spanning from 24.8 to 28.7 GHz at the lower band and from 36.2 to 40.8 GHz at the higher band.

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References

[1] L. Gavrilovska, V. Rakovic, and V. Atanasovski, "Visions towards 5g: Technical requirements and potential enablers," *Wireless Personal Communications*, vol. 87, pp. 731–757, 2016.

[2] R. Vannithamby and S. Talwar, *Towards 5G: Applications, requirements and candidate technologies*. John Wiley & Sons, 2017.

[3] A. Dkiouak, A. Zakriti, M. El Ouahabi, and A. Mchbal, "Design of a two symetrical f-shaped mimo antenna for wi-max and wlan applications," in *2019 International Conference on Wireless Technologies, Embedded and Intelligent Systems (WITS)*, pp. 1–6, IEEE, 2019.

[4] D. Bhargava, T. Padmavathy, Y. V. Reddy, N. Kavitha, and V. Hema, "Design and simulation of mimo antennas for mobile communication," in *IOP Conference Series: Materials Science and Engineering*, vol. 994, p. 012033, IOP Publishing, 2020.

[5] D. Konhar, S. Murmu, and H. Sethi, "2-element mimo antenna design using triangle-strip applicable for n258 band," in *2023 International Conference on Communication, Circuits, and Systems (IC3S)*, pp. 1–3, IEEE, 2023.

[6] A. Ahmad and D.-y. Choi, "Compact eight-element mimo antenna with reduced mutual coupling and beam-scanning performance," *Sensors*, vol. 22, no. 22, p. 8933, 2022.

[7] N. Sghaier, A. Belkadi, I. B. Hassine, L. Latrach, and A. Gharsallah, "Millimeter-wave dual-band mimo antennas for 5g wireless applications," *Journal of Infrared, Millimeter, and Terahertz Waves*, vol. 44, no. 3-4, pp. 297–312, 2023.

[8] A. E. Farahat and K. F. A. Hussein, "Dual-band (28/38 ghz) wideband mimo antenna for 5g mobile applications," *IEEE Access*, vol. 10, pp. 32213–32223, 2022.

[9] J. Saini and S. Agarwal, "Design a single band microstrip patch antenna at 60 ghz millimeter wave for 5g application," in *2017 international conference on Computer, Communications and Electronics (Comptelix)*, pp. 227–230, IEEE, 2017.

[10] M. I. Khattak, A. Sohail, U. Khan, Z. Barki, and G. Witjaksono, "Elliptical slot circular patch antenna array with dual band behaviour for future 5g mobile communication networks," *Progress In Electromagnetics Research C*, vol. 89, pp. 133–147, 2019.

[11] B. Yang, Z. Yu, Y. Dong, J. Zhou, and W. Hong, "Compact tapered slot antenna array for 5g millimeter-wave massive mimo systems," *IEEE Transactions on Antennas and Propagation*, vol. 65, no. 12, pp. 6721–6727, 2017.

[12] C.-X. Mao, S. Gao, and Y. Wang, "Broadband high-gain beam-scanning antenna array for millimeter-wave applications," *IEEE Transactions on Antennas and Propagation*, vol. 65, no. 9, pp. 4864–4868, 2017.

[13] M. AboEl-Hassan, A. E. Farahat, and K. F. Hussein, "Compact-size quad-band patch antenna for 5g mobile communications," *Microwave and Optical Technology Letters*, vol. 63, no. 12, pp. 3067–3071, 2021.

[14] C. A. Balanis, "Antenna theory analysis and design, a john wiley & sons," *Inc., Publication*, vol. 811, 2005.

[15] N. Ashraf, O. Haraz, M. A. Ashraf, and S. Alshebeili, "28/38-ghz dual-band millimeter wave siw array antenna with ebg structures for 5g applications," in *2015 International Conference on Information and Communication Technology Research (ICTRC)*, pp. 5–8, 2015.

[16] M. El Halaoui, L. Canale, A. Asselman, and G. Zissis, "Dual-band 28/38 ghz inverted-f array antenna for fifth generation mobile applications," in *Proceedings*, vol. 63, p. 53, MDPI, 2020.

[17] F. Arshad, A. Ahmad, Y. Amin, M. A. B. Abbasi, and D.-y. Choi, "Mimo antenna array with the capability of dual polarization reconfiguration for 5g mm-wave communication," *Scientific Reports*, vol. 12, no. 1, p. 18298, 2022.

[18] R. R. Elsharkawy, K. F. Hussein, and A. E. Farahat, "Dual-band (28/38 ghz) compact mimo antenna system for millimeter-wave applications," *Journal of Infrared, Millimeter, and Terahertz Waves*, pp. 1–22, 2023.