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A Compact Triple Band Dual Square Loop T-Shaped Monopole Antenna with Comb Shaped DGS for C, X, and Ku Band Application

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Abstract: In this paper a compact textile triple-band with comb-shaped DGS antenna is designed which operates in Sub- 6 GHz, Wifi, WLAN and X-band applications. The dimension of the antenna is $34 \times 22 \times 1.5$ mm^3 and it is fed by a 50 Ω micro-strip line. The ground plane uses a comb-shaped defected structure to improve bandwidth. The radiating patch is modified by adding two vertical lines and a pair of squares, which helps to achieve the required triple-band operation. The antenna operates 4.15 GHz, 7.53 GHz and 10.68 GHz. The design attains an impedance bandwidth of 0.63 GHz, 0.79 GHz and 4.88 GHz with a maximum gain of 6.6 dBi and radiation efficiency > 80%. This design effectively achieves multi-band operation with good efficiency making it suitable for advanced wireless communication systems.
Keywords: Triple band, DGS, monopole antenna.

I. INTRODUCTION

In recent years, wearable antennas have become increasingly important due to their ability to support lightweight, flexible and low cost wireless communication systems [1]. With the growing demand for high-speed data transmission in applications such as 5G, satellite communication and Internet of Things (IoT), there is a clear need for antennas with both compact size and capable of operating across multiple frequency bands. However designing such antennas for wearable uses is not easy as the human body effects antenna performance due to its high permittivity and power absorption, which can seriously affect antenna performance [1]. These antennas serve as the foundation for wireless body area networks (WBAN), enabling continuous health monitoring, real-time data transmission and seamless connectivity between medical sensors and external devices. The use of textile substrates such as felt and denim in wearable antenna fabrication is motivated by their low dielectric constant, which enhances the impedance bandwidth of the antenna. These materials are well suited for WBAN applications, offering lightweight, flexibility, cost-effective manufacturing and hard- ware simplicity [2], [3]. It has been demonstrated that the performance of the monopole antenna is significantly affected by the shape and size of the ground plane in terms of the operating frequency, impedance bandwidth and radiation patterns. In [4] an arc- shaped defected ground structure has been used to excite higher resonance frequencies and to improve impedance matching. Additionally in [5], by embedding different geometrical slots on the patch and tweaking the ground plane of the conventional antenna, wideband can be achieved. In [6] an inset-fed hexagonal- shaped MIMO antenna with T-shaped slots on the patch and slots on the ground plane has been designed for IoT and X- band applications, achieving dual bands at 2.5 GHz and 8.7 GHz with gains of 5.68 dBi and 5.51 dBi respectively. [7] presents triple-band all-textile monopole antenna for IoMT applications, utilizing an artificial magnetic conductor (AMC) array structure to achieve triple-band operation. In [8] textiles was used as a material for a wearable antenna for becoming more appealing due to their low weight, high flexibility and ease of incorporation into clothing. [9] presented a triple-band gap coupled microstrip patch antenna with inverted U-shaped open-ended slots and parasitic patches with a size of 40×50 mm^2 and gains of 4.45 dBi, 4.81 dBi, 5.26 dBi respectively In [10] bandwidth enhancement was achieved by using three notches along with an inverted-shaped notch, the gain of the compact microstrip patch antenna with a size of 38.4×46.8 mm^2 was stable, ranging from 2.9 dB to 3.84 dB. In [11] A 40×40 mm^2 compact quad-band antenna with the peak gain of 3.68 dBi, 4.89 dBi, 5.87 dBi and 5.8 dBi have been developed based on gap coupled horizontal and vertical strips ring-shape structure. [12] presented a dual-band line fed 39.04×47.64 mm^2 microstrip patch antenna with six notches in vertical rectangular shape for bandwidth enhancement with gains of 3.76 dBi and 3.80 dBi. [13] presented an implantable MIMO antenna where miniaturization was achieved using meandered structure and slots coupled in ground. But due to heavy losses in tissue environment it shows a gain of -28.2 dBi with a foot print of 4.5×6.2 mm^2.

This paper deals with the design of a symmetrical loop- loaded microstrip monopole antenna with defected ground structure on jeans substrate. The radiating element consist of two identical rectangular loop structures placed symmetrically on either sides of a centrally fed microstrip line, with embedded patches and connecting stubs. A comb-shaped DGS with rectangular slots was designed to help with impedance matching and bandwidth. The antenna design is simulated using ANSYS HFSS 2023 software. Based on its overall performance, the proposed structure is well suited for sub-6 GHz, X-band communication, making it promising candidate for modern wireless and body-centric communication systems.

II. ANTENNA DESIGN AND ANALYSIS

A. Geometry of Designed Antenna

Fig. 1 illustrates the structure of the proposed antenna, with the top consisting of the radiating element and a comb shaped structure in the bottom. The design is fabricated on a jeans substrate with thickness of 1.5 mm, and relative permittivity of 1.78 [14]. The overall geometry of the structure is 34 × 22 × 1.5 mm^3. The designed antenna achieves a triple frequency bands ranging from 3.88-4.50 GHz, 7.12-7.96 GHz and 9.89-14.77 GHz. The proposed design is simulated in ANSYS HFSS software. The optimized parameters of the proposed monopole antenna are given in Table I.

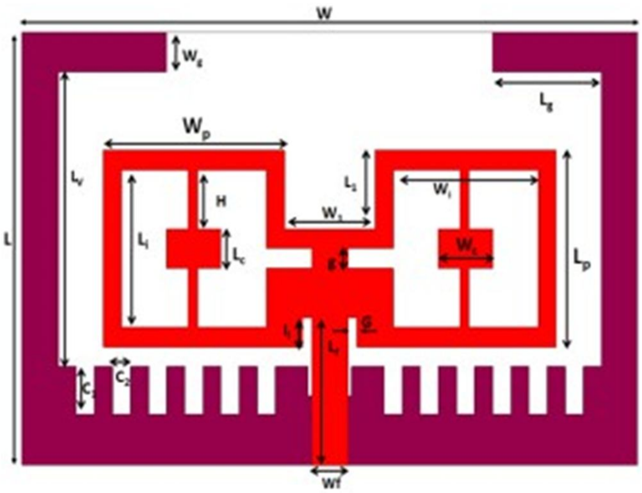

Fig. 1: Geometry of the proposed antenna.

TABLE I: Dimension Values of the Proposed Design.

Parameter	Dimension (mm)	Parameter	Dimensions (mm)
L	34	*Wg*	2
W	22	I_l	1.5
Lp	10	*Lg*	6
Wp	10	*Lv*	15
L_f	7.2	h_1	1.5
W_f	2	*g*	1
L_i	8	*H*	3
W_i	8	*G*	0.5
L_1	4	C_1	2.51
W_1	5	C_2	2.5
Wc	3	*Lc*	2

B. Evolutionary Steps of Antenna

The proposed monopole antennas design evolutionary steps are shown in Fig. 2. Initially, the design consists of a traditional micro-strip patch fed with a 50 ohm strip line, consisting of a full ground plane as depicted in Fig. 2 (a). The design operates at 8.91 GHz and 12.23 GHz, covering a frequency bands of 8.54-9.17 GHz and 11.88-12.63 GHz, as shown Fig. 2 (a). In step 2, two symmetrical squares of dimension 8 × 8 mm^2 respectively is etched on each side of the radiating patch to improve impedance matching, and introduced a partial ground plane to have an enhanced bandwidth, ranging from 10.79 to 14.91 GHz, at resonance frequency of 11.39 GHz as depicted in Fig. 2 (b). In the final step, Fig. 2 (c), a comb shaped design is introduced on the ground plane and a pair of are added to the radiating patch, creating an additional path for current flow, thus attaining a triple band response at 4.15 GHz, 7.53 GHz and 10.68 GHz, covering a frequency range of 3.88-4.51 GHz,7.18-7.97 GHz and 9.8914.77 GHz,

Fig. 2: Different steps of the design and suggested geometry.

III. RESULT AND DISCUSSION

A. S-parameter

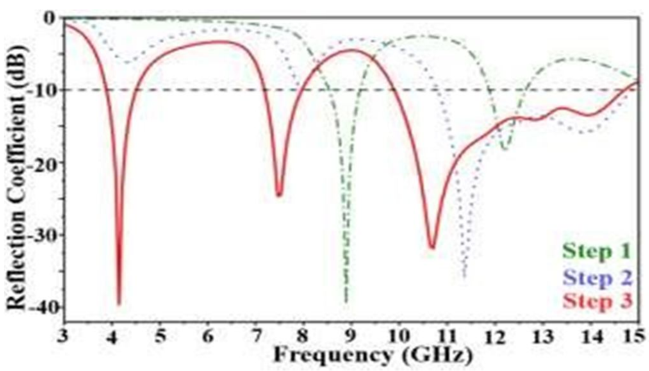

Fig. 3: Reflection coefficient (S_{11}) comparison for all three steps of antenna design variation.

Fig. 3 shows the return loss characteristics of proposed antenna for the step of evolution. Fig. 4 illustrates the simulated plot of the proposed monopole antenna design, resonating at 4.15 GHz, 7.53 GHz and 10.68 GHz. The designed attains an impedance bandwidth of 0.63 GHz, 0.79 GHz, and 4.88 GHz. The lower band ranges from 3.88-4.51 GHz, the mid band ranges from 7.187.97 GHz, and the upper band ranges from 9.89-14.77 GHz.

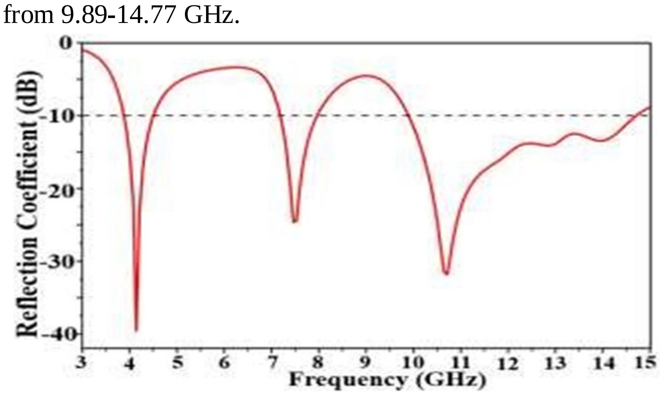

Fig. 4: Reflection coefficient (S_{11}) variation for different frequencies of proposed antenna.

B. Surface current distribution(SCD)

The surface current distribution (SCD) of the proposed antenna is depicted in Fig. 5 at three frequency bands, 4.15 GHz, 7.53 GHz, and 10.68 GHz respectively. Maximum concentration of the current is at the antenna feed of the proposed design and the current density gradually reduces as it moves away from the excited port.

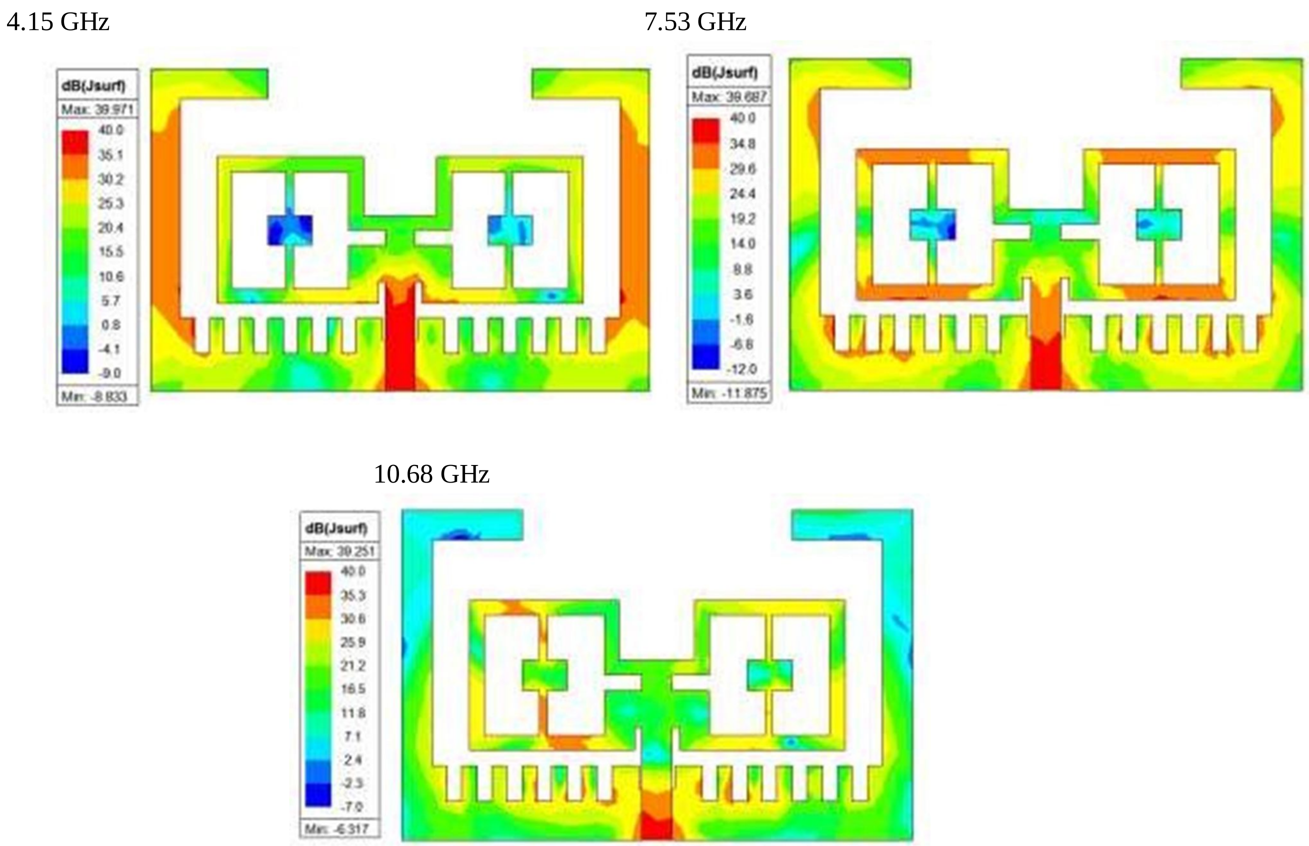

Fig. 5: Simulated current distribution for different resonance frequency of proposed antenna.

C. Gain and efficiency

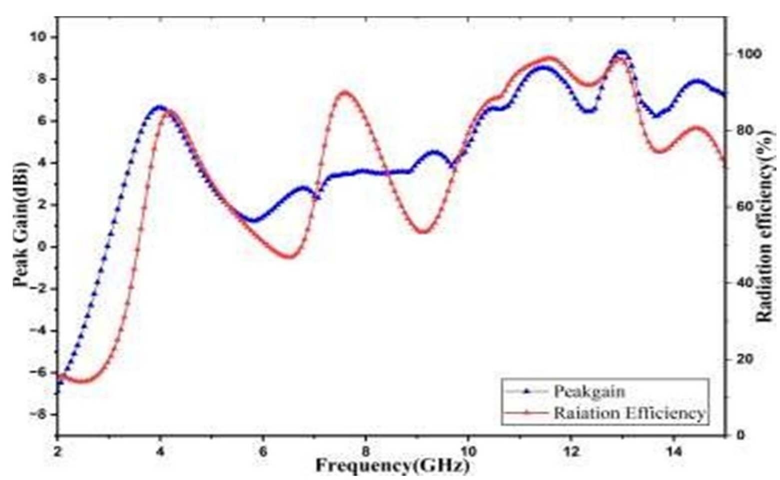

Fig. 6: Simulated gain and efficiency over frequency plot.

Fig. 6 depicts the simulated results of the gain and radiation efficiency of the proposed antenna. The design achieves a maximum gain of 6.6 dBi, as well as radiation efficiency of 80% for the entire operating frequency band.

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D. Radiation pattern

The radiation pattern of the proposed designed at resonant frequencies 4.15 GHz, 7.53 GHz and 10.68 GHz are illustrated in Fig 7 for E-plane in the left side and H-plane in the right side. At 4.15 GHz the E-plane represents a bidirectional pattern and the H-plane represents an omnidirectional pattern. At 7.53 GHz the E-plane exhibits a bidirectional pattern while the Hplane remains same. At 10.68 GHz, both the radiation patterns maintain the same pattern. As the frequency increases form 4.15 GHz to 10.68 GHz the E-plane represents a bidirectional pattern, while the H-plane maintains the omnidirectional behavior. Thus, the proposed design provides an efficient radiation performance with minimal power loss, making it suitable for C-band, X-band, WiMAX, WLAN applications.

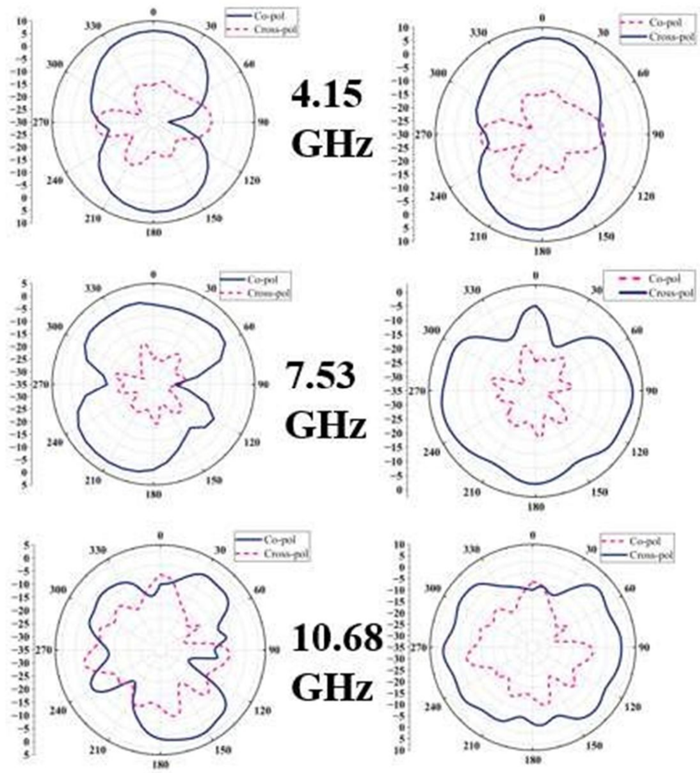

Fig 7: E-plane and H-plane radiation pattern of antenna gain for 4.15 GHz, 7.53 GHz and 10.68 GHz.

IV. CONCLUSION

A compact triple-band monopole antenna has been designed and simulated on jeans material for on-body applications. The design uses a dual square-loop T-shaped patch along with a comb-shaped defected ground plane and slots to achieve triple-band operation covering 3.88-4.50 GHz,7.12- 7.98 GHz and 9.89-14.77 GHz. The reflection coefficient stays well below -10 dB at all three resonance frequencies, with deep dips at 4.15 GHz,7.53 GHz and 10.68 GHz. A peak gain of 6.6 dBi is achieved at 10.68 GHz. The surface current distribution shows that different parts of the antenna contribute to different bands. The antenna is useful for the Sub-6 GHz Wi-Fi, WLAN and X-band applications.

TABLE II: Comparison of Proposed Antenna with Reference Designs

Ref. no.	Antenna Size (mm)	Gain (dB)	Efficiency(%)	Number of bands
[4]	40×25×1.6	1.14, 1.54, 2.26	NA	Triple
[5]	36×39×1.6	1.69, 2.79, 4.02	88, 98.6 ,93.7	Triple
[9]	40×50×1.6	4.45, 4.81, 5.26	89.5, 89, 90	Triple
[10]	38.4×46.8×1.6	3.84, 3.47	90.7, 90.3	Dual
[11]	40×40×1.6	3.68, 4.89, 5.87, 5.8	87, 89, 88, 88	Quadruple
[12]	39.04×47.6×1.6	3.76, 3.80	90, 89	Dual
This work	34×22×1.5	6.44, 3.44, 6.60	84.8, 89.6, 88.5	Triple

V. ACKNOWLEDGMENT

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REFERENCES

[1] R. Kumar, P. Bhardwaj, and M. Novita, "Comprehensive study on wearable substrates," in 2024 International Conference on Computing, Sciences and Communications (ICCSC), 2024, pp. 1–5.

[2] M. A. Abdelghany, M. I. Ahmed, A. A. Ibrahim, A. Desai, and M. F. Ahmed, "Textile antenna with dual bands and sar measurements for wearable communication," Electronics, vol. 13, no. 12, 2024. Available: https://www.mdpi.com/2079-9292/13/12/2251

[3] C. K. Nanda, S. Ballav, A. Chatterjee, and S. K. Parui, "A body wearable antenna based on jeans substrate with wide-band response," in 2018 5th International Conference on Signal Processing and Integrated Networks (SPIN), 2018, pp. 474–477.

[4] K. Chandra, M. Kumar, and M. D. Upadhayay, "Triple band compact monopole antenna for applications like Bluetooth, WiMAX and WLAN," IETE Journal of Research, vol. 69, no. 8, pp. 5654–5669, 2023. https://doi.org/10.1080/03772063.2021.1967791

[5] S. Wang, F. Kong, K. Li, and L. Du, "A planar triple-band monopole antenna loaded with an arc-shaped defected ground plane for WLAN/WiMAX applications," International Journal of Microwave and Wireless Technologies, vol. 13, no. 4, p. 381–389, 2021.

[6] P. Ramanujam, P. Ramesh Venkatesan, C. Arumugam, and M. Ponnusamy, "Design of miniaturized super wideband printed monopole antenna operating from 0.7 to 18.5 GHz," AEU - International Journal of Electronics and Communications, vol. 123, p. 153273, 2020. https://www.sciencedirect.com/science/article/pii/S1434841120308517

[7] C. N. Phaneendra and K. K. Naik, "Inset-fed quad-port hexagonal- shaped mimo t-shaped slots on patch with slots on ground plane antenna for IoT and x-band applications," Waves in Random and Complex Media, vol. 0, no. 0, pp. 1–14, 2024. https://doi.org/10.1080/17455030.2024.2404107

[8] F. R. Kareem, A. A. Ibrahim, and M. A. Abdalla, "Triple-band monopole textile wearable antenna for IoMT application," IEEE Sensors Journal, vol. 23, no. 19, pp. 23 377–23 387, 2023.

[9] R. K. Verma, V. Bali, A. Kumar, P. Pattanayak, R. K. Prasad, and M. Singh, "Design and analysis of Microstrip line fed gap coupled triple band slotted patch antenna for WiMAX, WLAN, and Sub-6GHz 5G applications," International Journal of Numerical Modelling: Electronic Networks, Devices and Fields, vol. 37, no. 6, p. e70005, 2024, e70005 JNM-24-1195.R1. : https://onlinelibrary.wiley.com/doi/abs/10.1002/jnm.70005

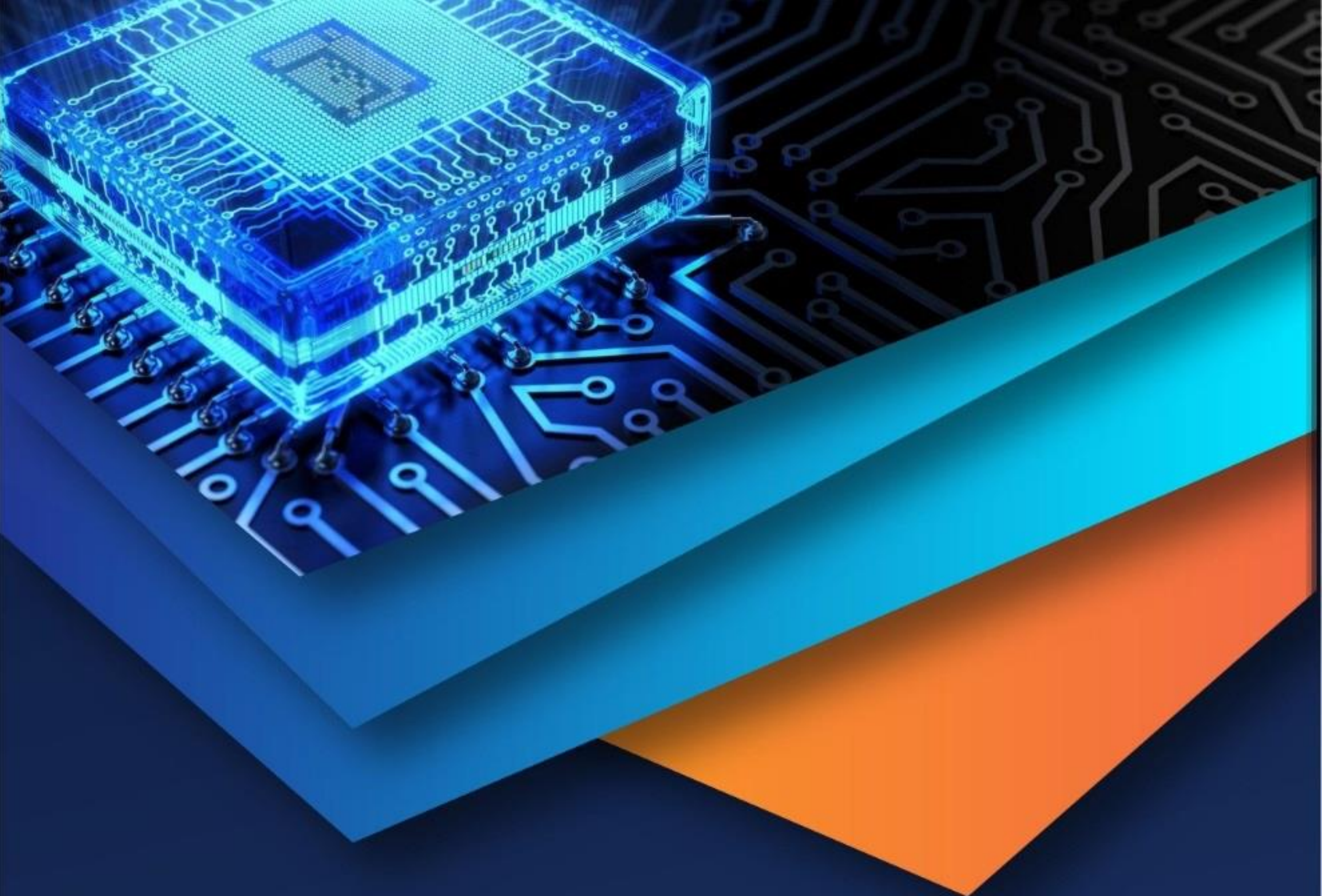
[10] R. K. Verma, "Bandwidth enhancement of an inverted f-shape notch loaded rectangular microstrip patch antenna for wireless applications in l and sband," Wireless Personal Communications, vol. 125, no. 1, pp. 861–877, 2022.

[11] S. Raikwar, A. Gupta, K. Srivastava, M. Singh, N. Anand, and R. K. Verma, "Design of compact and quad band gap coupled ring- shape microstrip patch antenna for WLAN/ISM/ WiMAX /5G applications," International Journal of Numerical Modelling: Electronic Networks, Devices and Fields, vol. 38, no. 3, p. e70060, 2025, e70060 JNM-24-1616.R2. https://onlinelibrary.wiley.com/ doi/abs/10.1002/jnm.70060

[12] R. K. Verma, V. Bali, P. Singh, A. Kumar, P. Pattanayak, V. K. Singh, and A. Yadav, "Modeling and circuit theory analysis of dual-band line fed microstrip patch antenna for the application of wireless communication," International Journal of Communication Systems, vol. 39, no. 1, p. e70325, 2026, e70325 IJCS-25-4246.: https://onlinelibrary.wiley.com/doi/abs/10.1002/dac.70325

[13] M. Bose, A. P. Singh, U. Chakraborty. (2025). "Design of a MIMO implantable antenna with ultra-miniaturized volume and reduced SAR". *Frequenz*, *79*(12), 91-99. https://doi.org/10.1515/freq-2024-0097.

[14] R. Pandey, A. K. Biswas, and U. Chakraborty, "A compact two-element UWB wearable MIMO antenna with reduced mutual coupling for body worn applications," IETE Journal of Research, vol. 71, no. 8, pp. 2715–2732, 2025. https: //doi.org/10.1080/03772063.2025.2496732



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