



REGULAR ARTICLE

Wearable Microstrip Patch Antenna with Notched Corners for Enhanced Multi-Band Performance

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The proposed wearable microstrip patch Antenna with notched corners for enhanced multi-band performance was designed, simulated, fabricated, and analysed. This antenna, which operates in three frequency bands whereas first frequency band is 2.83 to 3.16 GHz, second frequency band is 6.33 to 6.76 GHz and third frequency band is 8.71 to 9.64 GHz. So, the suggested antenna is a multi-band antenna, widely employed in many different applications because of its small size, minimal profile, and simplicity of circuit integration. These frequency range falls within the microwave spectrum and is suitable for many wireless communication systems. To improve the antenna's performance, a rectangular patch was modified as rectangular frame with notched corners and a full ground surface. Additionally, using jeans fabrics as a substrate offers versatility, enabling the antenna to be incorporated into clothing. The proposed antenna was fabricated with the measurement of 38 mm × 35 mm × 1 mm. The above frequency bands are utilized for satellite communication, including telemetry, tracking, and control, also used in *s*-band, *c*-band and *x*-band. This multi-band antenna frequency range is integral to modern wireless communication systems and continues to be a focus for innovation, especially with the growth of IoT, 5G, and other emerging technologies.

Keywords: Wearable antenna, Flexible, Notched corners, Multi-band, Jeans substrate.

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1. INTRODUCTION

These days, wearable antennas are an essential part of wireless communication systems, enabling seamless connectivity in applications such as healthcare monitoring, fitness tracking, smart textiles, and military communications [1, 2]. Designed to integrate with the human body or clothing, these antennas are characterized by their lightweight, flexible, and conformal nature, ensuring comfort and ease of wear. Operating in the frequency range of 2-5 GHz, wearable antennas are well-suited for a variety of widely used communication standards, including Wi-Fi (2.4 GHz, 5 GHz), Bluetooth, ZigBee, and even emerging 5G applications [3-5]. Particularly the 2-5 GHz frequency range is mainly advantageous for wearable antennas due to its balance between signal penetration and data transmission rates. Signals in this band offer sufficient bandwidth for high-speed data transfer while maintaining reasonable propagation through obstacles such as walls or the human body. [6] This makes them ideal for both indoor and outdoor environments, ensuring reliable and consistent performance across various scenarios. [7-8].

However, the design and development of wearable antennas present unique challenges. The closeness to the human body announces issues such as signal absorption, detuning, and impedance mismatches due to the body's dielectric properties. Additionally, the anten-

nas must maintain their performance under bending, stretching, or environmental conditions such as sweat or moisture. [9-10]. To address these challenges, wearable antennas often incorporate advanced materials, such as conductive textiles or flexible substrates, and feature innovative designs, such as planar structures, slots, and defected ground planes, to achieve optimal performance. A multi-band wearable patch antenna is designed to operate efficiently across multiple frequency bands. These are widely used in wireless communications, Radar applications and IoT devices. As wearable technology continues to advance, antennas resonating in the 2-5 GHz range play a critical role in enabling high-speed, low-latency, and reliable wireless communication [11], driving innovation across healthcare, sports, defence, and smart wearable industries. [12].

This paper is structured as follows: Section 2 details the proposed antenna design, emphasizing the development and simulation of the suggested structure. Section 3 examines the performance of the fabricated prototype with simulated results. Finally, Section 4 concludes the study and outlines potential future research directions.

2. ANTENNA DESIGN AND SIMULATION

The suggested antenna is composed of a flexible jeans substrate sandwiched between a rectangular

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patch with notched corners and a full ground surface. The design optimization steps with dimension and geometry of the suggested antenna are shown in Fig. 1. The provided image appears to show the design evolution of a wearable patch antenna, with a progression of designs featuring modifications such as corner notches for enhanced multi-band performance. The rectangular radiating patch has two notched corners with a length of L_p and width of W_p supported by the jeans substrate with dielectric constant, $\epsilon_r = 1.7$, loss tangent, $\tan\delta = 0.009$, and a thickness of $h = 1$ mm. The patch and microstrip feeding are composed of perfect metal. Initially, antenna 1 with a rectangular patch and full ground plane is simulated, which results in very poor resonance at 4 GHz. The antenna 2 was modified with a subtracted inner rectangular patch of length L_1 and width W_1 , it formed a rectangular frame with a gap length of W_{gap} . This antenna resonated at the frequency of 6 GHz and 9 GHz. Antenna 3 is modified with a partial ground ($L_g = 4$ mm), and notched corners at the top right and bottom left side of the antenna and then simulated, this resonated between 2.3 GHz to the 4.6 GHz at centre frequency of 2.7 GHz with a reflection coefficient of -30 dB. Finally, Antenna 4 was modified with the full ground surface with notched corner as shown in Fig. 1.

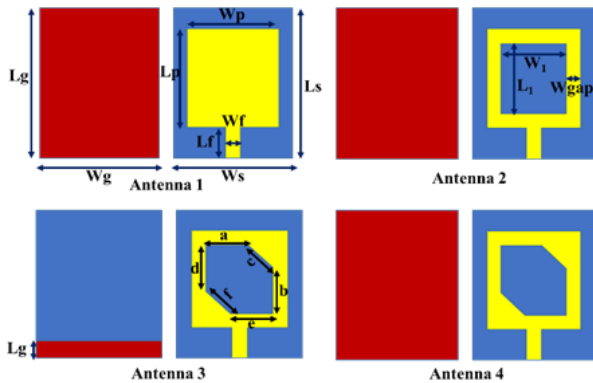


Fig. 1 – Design optimization of the suggested antenna

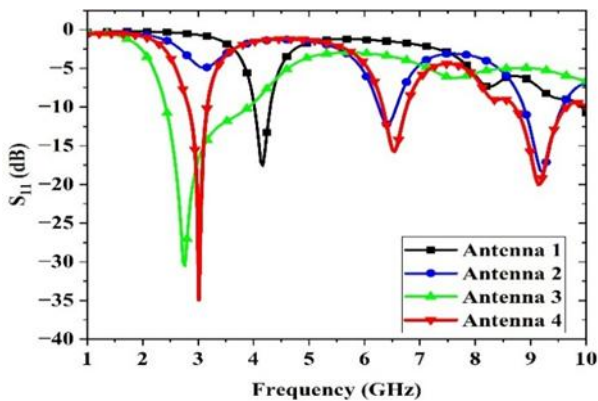


Fig. 2 – Simulated S_{11} Vs frequency of the design optimization

The full ground and two notches are introduced discontinuities that can lead to additional resonant frequencies, broadening the operational bandwidth. The optimized parameter values are shown in Table 1. This proposed antenna simulated analysis as shown in Fig. 2,

which operates in three frequency bands, first frequency band is 2.83 to 3.16 GHz, second frequency band is 6.33 to 6.76 GHz and third frequency band is 8.71 to 9.64 GHz. So, the suggested antenna is a multi-band antenna, widely employed in many different applications because of its compactness, minimal profile, and simplicity of circuit integration. The first band frequency ranges of 2.83 to 3.16 GHz fall within the s-band of the radio spectrum. The second frequency band 6.33 to 6.76 GHz is within c-band. The 8.71 to 9.64 GHz frequency band falls within the x-band. This multi-band antenna used for satellite communication, Radar systems and military applications. The proposed multi-band wearable patch antenna simulated analysis was done by HFSS.

Figure 3 illustrates the radiation pattern of a wearable patch antenna with notched corners operating at 3 GHz of the Antenna 4. The E -plane signifies the electric field's primary plane of oscillation. The radiation pattern shows two main lobes and nulls at certain angular around 90° and 270° . The pattern is symmetric, with maximum radiation in two opposite directions. This behavior is typical for a patch antenna operating in its fundamental TM_{10} . The H -plane represents the magnetic field's oscillation plane, orthogonal to the E -plane. The pattern is more uniform and nearly omnidirectional in this plane.

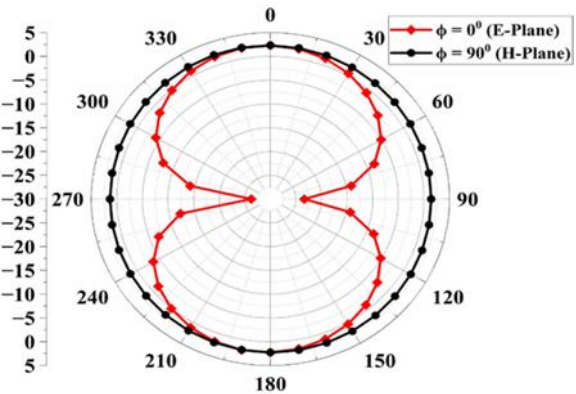


Fig. 3 – Radiation pattern of the suggested antenna

The radiation pattern demonstrates the stability and functionality of the notched design at 3 GHz, confirming its suitability for wearable and flexible devices. The gain drops to the minimum at specific angles (nulls), reflecting destructive interference in those directions. The 3D gain of the suggested antenna 3 as shown in Fig. 4. The gain of this antenna 3 is 4.45 dBi.

Table 1 – Optimized parameters with values

Parameter	L_s	W_s	L_p	W_p	L_1	W_1
Value (mm)	38	35	26	24	20	18
Parameter	h	L_f	W_f	W_{gap}	A	b
Value (mm)	1	10	3	3	13.5	15
Parameter	c	d	e	f	L_g	W_g
Value (mm)	6.73	15	13.5	6.73	38	35

The surface current distribution of a wearable patch antenna with notched corners is shown in Fig. 5. This visualization highlights how current flows on the antenna surface, giving insight into its resonance and radiation characteristics. The higher current regions are concentrated near the feedline, along the edges of the main patch, and around the notched corners. High current density at the feedline indicates efficient power delivery from the source to the antenna. Strong currents along the edges suggest that these areas contribute significantly to radiation, as edge currents create fringing fields responsible for far-field radiation.

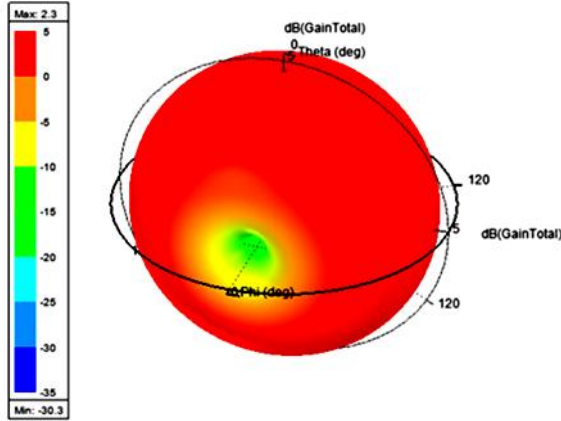


Fig. 4 – 3D Gain of the suggested antenna

The surface current distribution reveals that the notched corners effectively modify the antenna's electrical properties, enhancing multi-band of frequencies with considerable bandwidth. The high-current regions along the edges and feedline confirm efficient radiation and power delivery, while the overall distribution ensures performance stability for wearable applications.

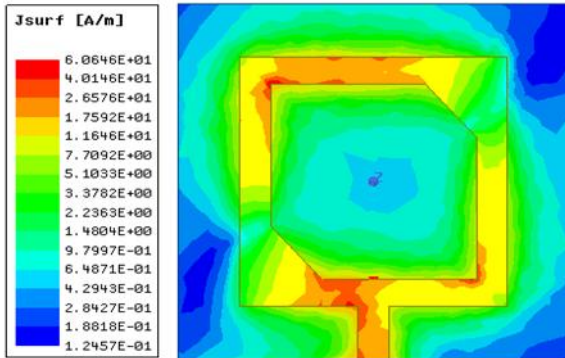


Fig. 5 – Current distribution of the suggested antenna

The parametric analysis of the suggested antenna was done by the variations of the antenna gap length W_{gap} from 6 mm down to 3 mm as shown in Fig. 6. When $W_{gap} = 6$ mm, the antenna resonates at 2.7 GHz and 8.5 GHz with limited bandwidth. When $W_{gap} = 5$ mm, the antenna resonates at 2.7 GHz with increased bandwidth. When $W_{gap} = 4$ mm, the antenna resonated at 2.8 GHz and 9.5 GHz. When $W_{gap} = 3$ mm, the antenna operates at multiband, the first frequency band is 2.83 to 3.16 GHz, second frequency band is 6.33 to 6.76 GHz and third frequency band is 8.71 to 9.64 GHz. Hence, W_{gap} parameter was fixed at 3 mm.

Table 2 – Dielectric properties of the Human Tissue [8].

Human Tissue	Density (Kg/m ³)	Permittivity (ϵ_r)	Conductivity (s/m)	Loss tangent (δ)
Skin	1109	38.07	1.46	0.28
Fat	911	5.28	0.11	0.15
Muscle	1060	52.72	1.74	0.24
Bone	1008	18.54	0.81	0.32

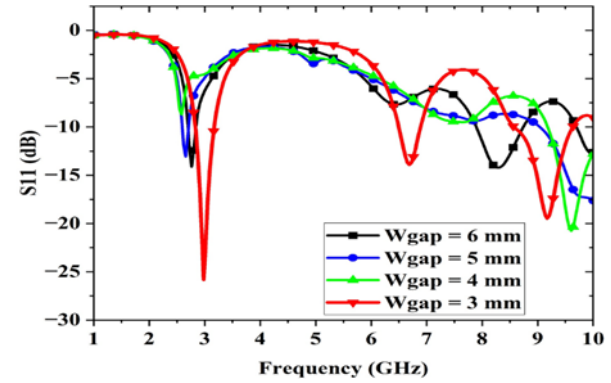


Fig. 6 – W_{gap} analysis of the suggested antenna

The simulation of the Specific Absorption Rate (SAR) distribution for a wearable antenna with notched corners as illustrated in Fig 7. SAR is a measure of the rate at which energy from an electromagnetic field is absorbed by a unit mass of organic tissue, typically expressed in watts per kilogram (W/kg). This SAR simulation provides critical insights into how the antenna interacts with biological tissue, ensuring it complies with safety standards such as IEEE or ICNIRP guidelines for maximum SAR levels in wearable devices. The design of the notched corners likely contributes to optimizing the antenna's safety and performance. The human phantom layers are designed as four layers as shown in Fig. 8 of skin (2 mm), fat (5 mm), muscle (20 mm), and bone (13 mm) with the measurements of 38 mm $\times$ 35 mm $\times$ 40 mm as shown in Table 2.

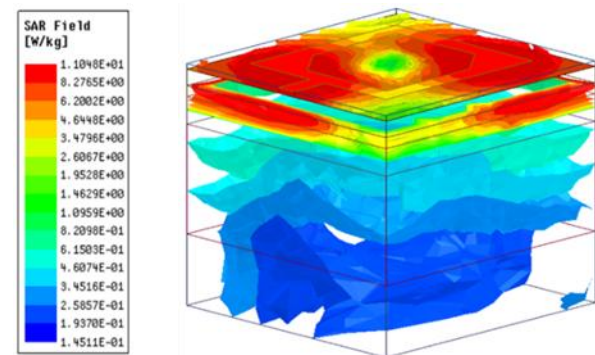


Fig. 7 – The SAR simulation of the suggested antenna

3. MEASURED RESULTS AND DISCUSSIONS

The prototype of the multi-band wearable patch antenna with notched corners is shown in Fig. 9. The measured results are compared with the simulation results, which illustrated in Fig. 10. Measured results generally follow the simulated trend, some deviations

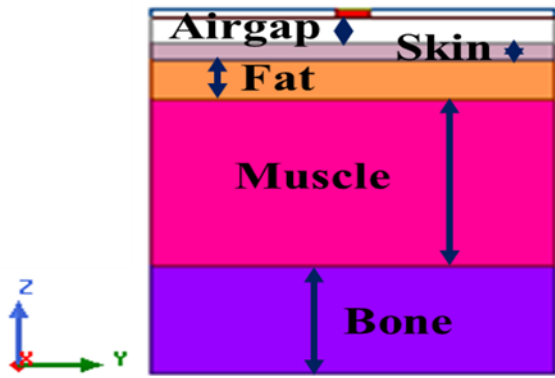


Fig. 8 – The human phantom layers of the suggested antenna

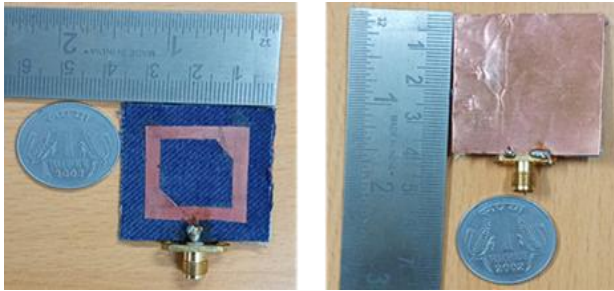


Fig. 9 – The proto type of the suggested antenna

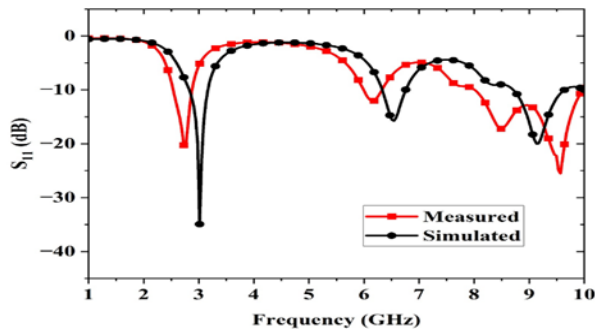


Fig. 10 – The simulated Vs measured results of the antenna

Table 2 – Present work comparison with related work

Ref	Frequency Band (GHz)	Bandwidth (%)	Total Size (mm ²)
[3]	2.4/5.8	3.8/5.2	41 × 44
[4]	3.5/5.8	NA	86 × 86
[9]	3.5/4/4.2	NA	154 × 70
[10]	2.45/3.32/3.93/5.8	3.7/5.7/5.85/9.8	60 × 60
Prop.	2.83 - 3.16 6.33 - 6.76 8.71 - 9.64	11.02 6.57 10.14	38 × 35

occur due to fabrication tolerances, measurement inaccuracies, and environmental factors. Overall, both results show good agreement, indicating that the simulation accurately predicts real-world performance, with minor discrepancies likely due to practical imperfections. The suggested antenna also compared with related existed works as shown in Table 3.

4. CONCLUSION

The wearable microstrip patch antenna with notched corners for enhanced multiband performance was designed, simulated, analysed, and presented here. The antenna design represents the culmination of iterations, focusing on maximizing bandwidth, improving efficiency, and ensuring a compact form factor suitable for wearable applications. The introduction of slots and corner notches significantly broadens the usable frequency range and generate multi-band. This antenna, compact at $38 \times 35 \times 1$ mm³, operates in three frequency bands, first frequency band is 2.83 to 3.16 GHz, second frequency band is 6.33 to 6.76 GHz and third frequency band is 8.71 to 9.64 GHz. The SAR simulation was also done and it satisfies the allowable maximum level that is 1.104 W/Kg. This antenna is widely employed in many different applications because of its small size, minimal profile, and simplicity of circuit integration. The proposed antenna design can be further refined to meet the growing demands of next-generation wearable technologies.

REFERENCES

1. A.L. Sharon Giftsy, U.K. Kommuri, R.P. Dwivedi, *IEEE Access* **12**, 90016 (2024).
2. U. Ali, S. Ullah, B. Kamal, L. Matekovits, A. Altaf, *IEEE Access* **11**, 14458 (2023).
3. U. Musa et al., *IEEE Access* **11**, 30996 (2023).
4. M. El Atrash, M.A. Abdalla, H.M. Elhennawy, *IEEE Trans. Antennas Propag.* **67** No 10, 6378 (2019).
5. Q.H. Dang, S.J. Chen, N. Nguyen-Trong, C. Fumeaux, *IEEE Trans. Antennas Propag.* **72** No 1, 243 (2024).
6. R.K. Baudh, S. Sahu, M.S. Parihar, V. Dinesh Kumar, *IEEE Trans. Circuits Syst. II Express Briefs* **71** No 2, 567 (2024).
7. P.B. Samal, S.J. Chen, C. Fumeaux, *IEEE Trans. Antennas Propag.* **71** No 2, 1391 (2023).
8. U. Ali, S. Ullah, A. Basir, B. Kamal, L. Matekovits, H. Yoo, *IEEE Access* **11**, 73894 (2023).
9. M. Bendaoued et al., *J. Nano- Electron. Phys.* **15** No 4, 04014 (2023).
10. H. Li, J. Du, X.X. Yang, S. Gao, *IEEE Antennas Wireless Propag. Lett.* **21** No 4, 779 (2022).
11. B. Roy, A.K. Bhatterchya, S.K. Choudhury, *2013 Int. Conf. Microw. Photonics, ICMAP 2013* (2013).
12. M.M.H. Mahfuz et al., *IEEE Access* **10**, 38406 (2022).

Мікросмужкова патч-антена з виїмчастими кутами для покращеної багатодіапазонної продуктивності

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Було розроблено, змодельовано, виготовлено та проаналізовано запропоновану носиму мікросмужкову антену з надрізами на кутах для покращеної багатодіапазонної продуктивності. Ця антена працює у трьох частотних діапазонах, де перший діапазон частот становить від 2,83 до 3,16 ГГц, другий діапазон частот - від 6,33 до 6,76 ГГц, а третій діапазон частот - від 8,71 до 9,64 ГГц. Отже, запропонована антена є багатодіапазонною антеною, яка широко використовується в багатьох різних застосуваннях завдяки своїм малим розмірам, мінімальному профілю та простоті інтеграції схеми. Цей діапазон частот потрапляє в мікрохвильовий спектр і підходить для багатьох систем бездротового зв'язку. Для покращення продуктивності антени прямокутний антенний елемент був модифікований як прямокутна рама з надрізами на кутах та повною ґрунтовою поверхнею. Крім того, використання джинсової тканини як підкладки забезпечує універсальність, дозволяючи інтегрувати антену в одяг. Запропонована антена була виготовлена з розмірами 38 мм × 35 мм × 1 мм. Вищезазначені частотні діапазони використовуються для супутникового зв'язку, включаючи телеметрію, відстеження та керування, а також використовуються в s-діапазонах, c-діапазонах та x-діапазонах. Цей багатодіапазонний частотний діапазон антен є невід'ємною частиною сучасних систем бездротового зв'язку та продовжує бути центром інновацій, особливо з розвитком Інтернету речей, 5G та інших нових технологій.

Ключові слова: Антена, Гнучка підкладка, 3 надрізами на кутах, Багатодіапазонна, Джинсова підкладка.