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REGULAR ARTICLE

Wearable MIMO Antenna for Health Monitoring Applications

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The increasing need for wearable health monitoring gadgets has led to the development of better antenna technology for reliable wireless communication in small, wearable designs. This paper introduces a new way to create a wearable Multiple-Input Multiple-Output (MIMO) antenna specifically for health monitoring. Working at the sub 6 GHz frequency, this antenna allows fast data transfer and effective communication between wearable devices and healthcare systems. The selection of polylactic acid (PLA) as the substrate material offers several advantages for wearable applications. PLA boasts superior flexibility, simplifies the fabrication process, and ensures compatibility with the form factor of wearable devices. The antenna's construction involves meticulous steps like resin preparation, extrusion, and surface treatments to achieve the desired dimensions and optimize its performance. The uniqueness of this work lies in of developing a smaller-sized (29x19mm^2) antenna to improve signal reception with -45 dB isolation between the antennas and ensure dependable wireless communication. Through meticulous testing and model construction, the antenna design is refined by incorporating additional antenna components to enhance signal quality, mitigate issues, and optimize overall system performance.

Keywords: MIMO, PolyLactic Acid(PLA), Wearable antenna, Health monitoring, Flexible.

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1. INTRODUCTION

Fueled by the rising demand for wearable health monitoring devices, advancements in antenna technologies are paving the way for reliable wireless communication within compact, user-worn form factors. In this evolving landscape, Multiple-Input Multiple-Output (MIMO) antennas have emerged as a pivotal solution, facilitating seamless data exchange between wearable devices and healthcare systems. This review delves into significant studies, each offering valuable insights into the design and application of MIMO antennas for health monitoring.

Existing research showcases diverse antenna configurations, including textile-based antennas for comfort and flexibility ([1]), tri-band belt strap antennas for adaptability in IoMT applications ([2]), and wide-bandwidth all-textile PIFAs addressing bandwidth limitations in WLAN scenarios ([3]). Additionally, studies explore self-decoupled dual-band PIFAs specifically tailored for Wi-Fi 6E smart watch MIMO applications ([4]), compact antennas with high-impedance surfaces for wearable ([5]), and dual-band wearable MIMO antennas for Wi-Fi sensing ([6]). Furthermore, research in [7] explores polarization conversion meta surfaces MIMO antennas for biomedical applications, while [8,9,10] focuses on enhancing isolation in compact textile MIMO antennas [11, 12] for interference reduction using T stubs on ground plane which is suitable for diverse wireless telecommunication and medical applications.

Examining these studies reveals a diverse range of antenna parameters, reflecting the multifaceted nature of MIMO technology. Operating frequencies vary from 5.2 GHz to cater to specific healthcare communication needs, with some studies exploring dual-band and tri-band configurations. To enhance performance, polarization strategies such as dual-polarized and circular high-impedance surfaces are employed. Gain, a crucial indicator of signal strength, varies based on the antenna design, while bandwidth considerations address the challenge of accommodating high data transmission rates. Applications for these MIMO antennas encompass diverse areas, including medical wearable monitoring systems, IoT, WLAN, smart watch MIMO, wearable, Wi-Fi sensing, biomedical applications, and general wireless telecommunication and medical uses.

Common methodologies employed in the development of these antennas include the utilization of advanced materials like textiles for flexibility and comfort, 3D printing for precise and flexible fabrication, and the integration of MIMO technology to enhance signal diversity and reliability. Additionally, techniques such as circular high-impedance surfaces, metasurfaces, and isola-

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tion enhancement slots are explored for further performance improvements.

Collectively, these studies highlight the ongoing effort to strike a balance between achieving optimal antenna performance and ensuring user comfort within wearable form factors. Key challenges identified include miniaturization without compromising performance, potential detuning effects due to the human body's proximity to the antenna, and the need for extensive real-world testing to validate antenna reliability in various usage scenarios.

To address these limitations, a novel and advanced wearable MIMO antenna system is proposed for health monitoring applications. This system aims to provide a user-friendly and wireless solution that prioritizes comfort, mobility, and reliable communication. The MIMO antenna, specifically designed for integration into wearable devices, facilitates continuous and unobtrusive health monitoring. Operating at the sub 6 GHz frequency range, the proposed system offers advantages such as high data transmission rates, low interference, and compatibility with existing wireless protocols used in healthcare settings. Polylactic acid (PLA) is chosen as the substrate material due to its biodegradability, flexibility, ease of processing, and compatibility with wearable [13]. The MIMO antenna design incorporates strategically placed multiple antenna elements on the wearable device, enabling improved signal diversity, reduced interference, and enhanced overall system performance. By leveraging the benefits of MIMO technology, the proposed system aims to overcome challenges related to signal fading, multipath propagation, and interference, ultimately resulting in reliable and accurate wireless communication between the wearable device and healthcare systems.

This combined approach, encompassing a review of existing research and the introduction of a novel solution, aims to contribute to the advancement of wearable MIMO antennas for improved healthcare communication and patient monitoring capabilities.

2. PROPOSED MIMO ANTENNA DESIGN

The proposed system utilizes polylactic acid (PLA) as the substrate material for the antenna. The mimo antenna was designed using conventional patch. The fabrication process involves converting PLA into a sheet using polymerization and refining techniques. This sheet is then extruded to achieve the desired dimensions and characteristics. Further processing techniques, such as trimming, cutting, and optional surface treatment, are employed to shape the PLA sheet into an optimized antenna structure. The dielectric constant of PLA material is 2.7 used in this work with thickness of 1mm and loss tangent of 0.009.

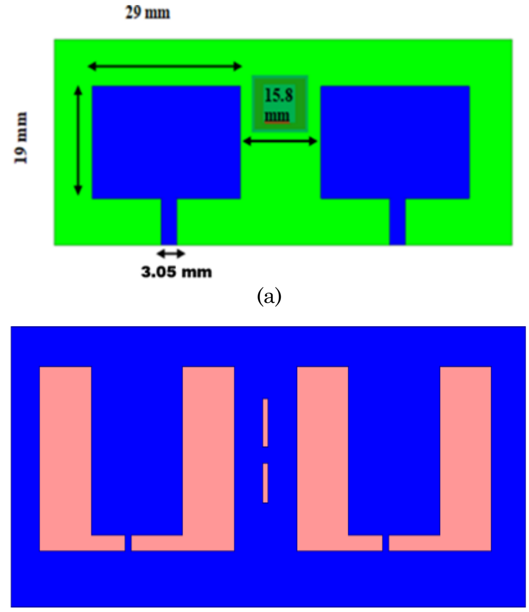
The conventional patch antenna design is followed for designing a mimo antenna for 3.5 GHz frequency (5G application) with dimension of 29 × 19 mm^2. The design equations of patch width 'w' and patch length 'L', involved are provided in equation from 1 to 3 [14].

$$w = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \quad (1)$$

$$L = \frac{c}{2f_r\sqrt{\varepsilon_{eff}}} - 2\Delta L \quad (2)$$

$$fr = \frac{c}{2L\sqrt{\varepsilon_r}} \quad (3)$$

Here, the speed of the light is represented by 'c' and dielectric constant of the substrate is represented by 'ε_r', where (ε_r = 2.7). ΔL is effective length and the ε_{eff} is effective dielectric constant.



(a)

(b)

Fig. 1 – Structure of the Simulated MIMO Antenna (a) front view (b) back view

The above designed antenna is placed above the PLA substrate material with the separation of 15.8 mm which is equivalent to (λ_g/4) for making an MIMO antenna.

For isolation between antennas slots were introduced at the ground plane in between MIMO antenna. This MIMO antenna structure is simulated using HFSS tool and the performances were analyzed.

3. RESULTS AND DISCUSSION

The simulation of the proposed MIMO antenna structure is discussed in this section. In Fig. 2, the s_{11} and S_{12} parameters are shown. It is evident from the Fig 2 that the designed antenna resonates around 3.5 GHz frequency. The S_{12} shows nearly – 45 dB which exhibits good isolation between the antennas.

For further evidence, current distribution was analyzed in the simulation which is shown in Fig. 3. when the first antenna excited the current distribution of the second antenna were not influenced much and vice versa.

For the purpose of validating the analysis, the suggested SIW filter has been simulated, made, and tested.

In Fig. 4, the radiation pattern of proposed MIMO antenna was presented in E and H plane. The field patterns were obtained as similar as convention radiation pattern. Each simulated single antenna contributes 4.18 dB gain which is desirable for wearable 5G applications.

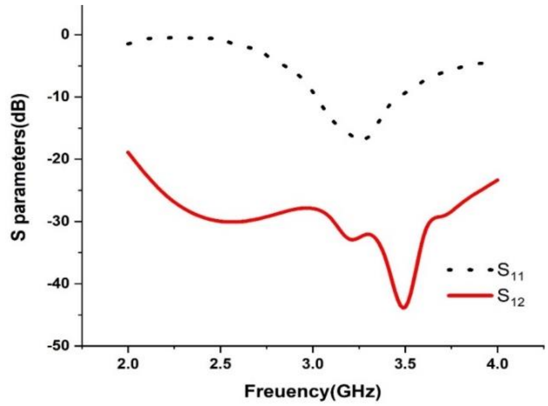
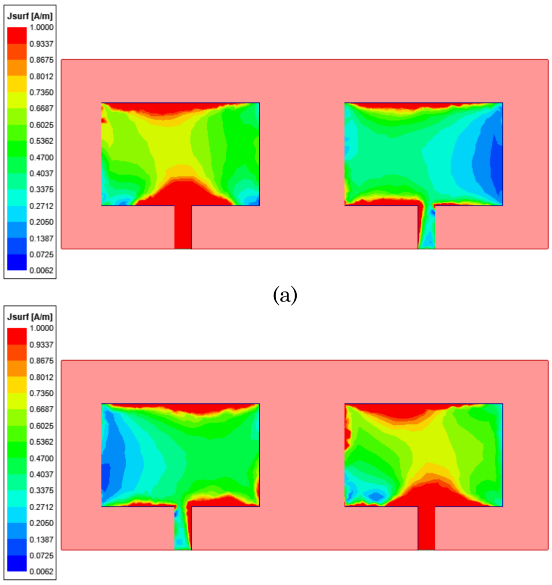


Fig. 2 – Simulated *S* parameter of MIMO antenna



(a)

(b)

Fig. 3 – Current distribution of MIMO antenna

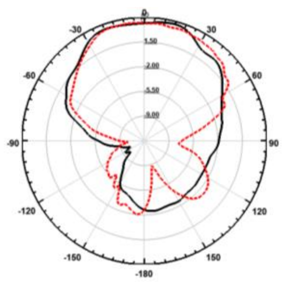


Fig. 4 – Radiation pattern $\varphi = 0$ and $\varphi = 90$

The simulated antenna is fabricated and measured using vector network analyzer (VNA) which is given in Fig. 5 and Fig. 6.

The measured frequency response of the antenna structure results reveal that frequency operates from 3.2 GHz to 3.55 GHz with a high level of isolation which is good for wearable MIMO.

Fig. 5 – Fabricated wearable MIMO

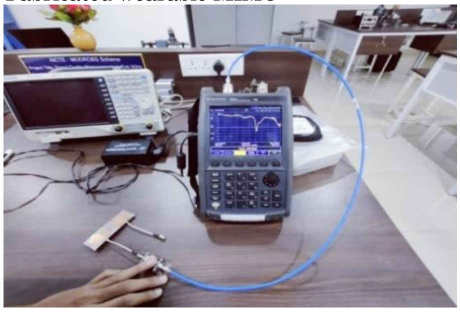


Fig. 6 – Vector network measurement

Table 1 – Performance comparison of proposed design with existing wearable MIMO antenna

Ref.	Substrate	Isolation (dB)	Bandwidth	Size (mm²)	No of ant
[14]	Silicone rubber	> 25	2.75–12	10 × 40	2
[15]	Textile	< 23	2.4–5.8	30 × 58	2
[16]	FR4	> 30	3.4–3.6 GHz	40 × 40	2
[prop work]	PLA	> 40	3.2 to 3.55	29 × 19	2

In Table 1 comparison analysis of existing 2 element MIMO antenna was discussed. From the analysis, the observed results agree with those predicted by simulation. Comparison made with different substrates such as silicon rubber, FR4 and textiles. Antenna parameters such as isolation, bandwidth, and size were compared. The proposed PLA based MIMO antenna exhibits better isolation (> 40 dB) compared to other design antennas with compact size (29 × 19). Hence the proposed antenna size is extremely small and suited for use in wearable MIMO applications operating at sub 6 GHz band.

4. CONCLUSIONS

PLA based 2 × 2 MIMO patch antenna was proposed in this article. This structure operated from 2.9 to 3.55 GHz frequency band. The proposed filter structure is simulated, fabricated. With better isolation (> 45 dB) it can be easily integrated on any wearable device. From the 3 dB bandwidth, better isolation and good return loss and gain (> 4 dB) suitable for sub 6GHz band.

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Портативна MIMO-антена для додатків моніторингу здоров'я

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Зростаюча потреба в гаджетах для моніторингу здоров'я, які можна носити, призвела до розробки кращої технології антени для надійного бездротового зв'язку в невеликих конструкціях, які можна носити. У цьому документі представлено новий спосіб створення носимої антени з кількома входами та кількома виходами (MIMO) спеціально для моніторингу здоров'я. Працюючи на частоті нижче 6 ГГц, ця антена забезпечує швидку передачу даних і ефективний зв'язок між носимими пристроями та системами охорони здоров'я. Вибір полімолочної кислоти (PLA) як матеріалу підкладки дає кілька переваг для носіїв. PLA може похвалитися надзвичайною гнучкістю, спрощує процес виготовлення та забезпечує сумісність із форм-фактором носимих пристроїв. Конструкція антени передбачає ретельні кроки, такі як підготовка смоли, екструзія та обробка поверхні для досягнення бажаних розмірів і оптимізації її продуктивності. Унікальність цієї роботи полягає в розробці антени меншого розміру (29×19 мм^2) для покращення прийому сигналу з ізоляцією – 45 дБ між антенами та забезпечення надійного бездротового зв'язку. Завдяки ретельному тестуванню та конструюванню моделі конструкція антени була вдосконалена шляхом включення додаткових компонентів антени для покращення якості сигналу, пом'якшення проблем і оптимізації загальної продуктивності системи.

Ключові слова: MIMO, PolyLactic Acid(PLA), Портативна антена, Моніторинг здоров'я, Гнучкість.