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REGULAR ARTICLE

Optimized Dual Coupling PIFA for Low SAR Smartphone and Wearable Applications

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PIFAs are valued for their compact size, low profile, and ability to provide good radiation efficiency for wireless applications. The proposed PIFA resonates at 2.4 GHz frequency with better radiation efficiency and gain performance. For the proposed PIFA operating at this frequency, contains a patch size dimension of 22×7.25 mm² and possesses substrate height of 1.3 mm. The novel aspect of this proposed design is broadband width and achieved a better performance. The design of a PIFA also includes a shorting pin, which connects the radiating patch to the ground plane. This feature helps to reduce the overall size of the antenna by lowering the resonant frequency, making PIFA highly suitable for compact devices like smartphones, tablets, wearables, and IoT devices. The shorting pin and the feed pin work together to ensure that power is efficiently transferred to the antenna for radiation, thus maximizing its performance within the frequency band. The shorting pin, which connects the radiating patch to the ground, plays a key role in reducing the antenna's size by lowering its resonant frequency. For smartphone applications, the dual coupling PIFA, with dimensions of 25×10.8 mm² and a fully covered copper ground plane, demonstrated remarkable efficiency and SAR reduction capabilities. The designed antenna will operate at 2.35 to 2.45 GHz frequencies respectively.

Keywords: PIF antenna, SAR, Wearable applications, Resonant frequency.

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1. INTRODUCTION

The antenna is commonly used in Bluetooth devices such as headphones, smartwatches, and fitness trackers, where compactness and omnidirectional radiation are critical. In addition, PIFAs are also integrated into Wi-Fi devices and ZigBee-based IoT systems, offering reliable performance in short-range wireless communication. Overall, PIFAs operating at 2.4 GHz are essential in providing efficient and consistent wireless connectivity in modern electronic devices [1]. The designed antenna is proposed by Bluetooth energy communication which is commonly used in modern devices at 2.44 GHz. Considering it is to be used for a wearable device, it must be small in size and resistant to mechanical and temperature variations. An optimized planar inverted-F antenna (PIFA) with parasitic element is used to broaden the antenna bandwidth. The parasitic element's end is shorted to reduce the patch size to 22×7.25 mm^2, making it suitable for wearable devices such as Smartwatches [2-3]. Also, the ground layer of antenna allows it to radiate well externally while interfering minimum with the internal medium behind it. As a result, the reflection coefficient is not affected by the changes in the internal medium. The maximum gain of the antenna is 9.42 dBi, and its impedance bandwidth ranges from 2.35-2.45 GHz. Finally, the antenna can be fabricated into a wearable electronic device. The Planar Inverted-F Antenna (PIFA) has emerged as a highly effective solution for Bluetooth applications in wearable devices [4]. Its compact design, low-profile structure, and efficient performance make it ideally suited for the space-constrained environments of modern wearable technology. By operating effectively within the 2.4 GHz band, PIFA antennas enable seamless wireless communication, which is crucial for devices such as smartwatches, fitness trackers, and wireless earbuds [5-7]. The PIFA's ability to achieve a good balance between size and functionality, combined with its omnidirectional radiation pattern, ensures reliable connectivity and robust signal quality in various orientations [8-10]. Additionally, the incorporation of features like shorting pins and parasitic elements further enhances the antenna's bandwidth and gain, making it adaptable to diverse application requirements. As Bluetooth technology continues to evolve and expand into new domains, the relevance of PIFA antennas in wearable devices is likely

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to increase. Their versatility, efficiency, and suitability for miniaturization position PIFA antennas as a cornerstone in the development of next-generation Bluetooth-enabled wearables, enabling innovative features and enhancing user experiences across various applications. A PIFA with dimensions of 25 × 10.8 mm^2 and a completely covered ground made of copper was simulated. The structure is fed by a microstrip line feed. Because of its compact size, improved radiation efficiency, *E*-field, *H*-field, and surface current resonant frequency it is suitable for Bluetooth wearables like Smart watches and various medical applications.

2. ANTENNA DESIGN

Fig. 1 shows the ground layer design of a PIFA. The green region represents the ground plane of the antenna, which is a critical component in the design for proper radiation performance and impedance matching. Fig. 2 illustrates the substrate layer design of a PIFA. The red region represents the dielectric substrate, which serves as a supporting medium for the antenna structure and plays a critical role in determining the antenna's electromagnetic properties. Fig. 3 shows the radiating patch of the PIFA and it is primarily responsible for generating and radiating electromagnetic waves when an RF signal is applied to it. Fig. 4 shows the front view of overall designed antenna. It contains patch, substrate and a parasitic element. Fig. 5 shows the overall view of the designed PIFA. It shows the combination of all elements present in antenna and how the patch and substrate are connected through the connecting pin.

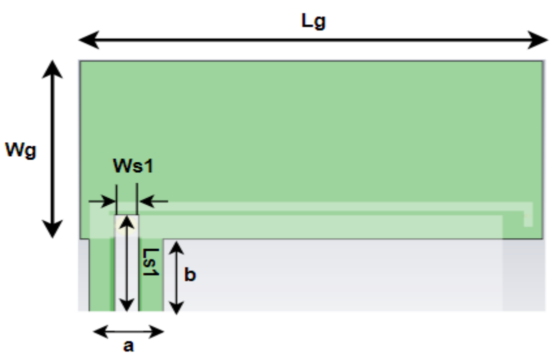

Fig. 1 – Ground layer

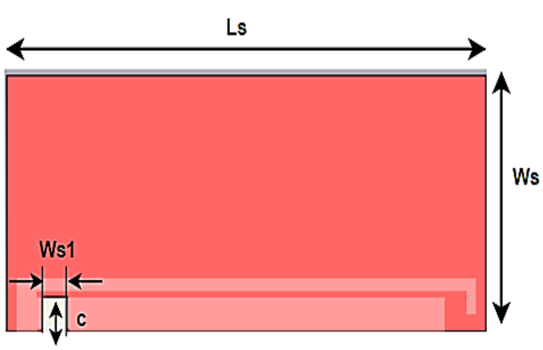

Fig. 2 – Substrate layer

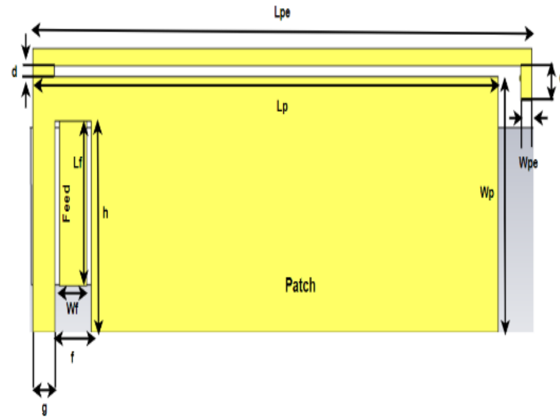

Fig. 3 – Radiating patch

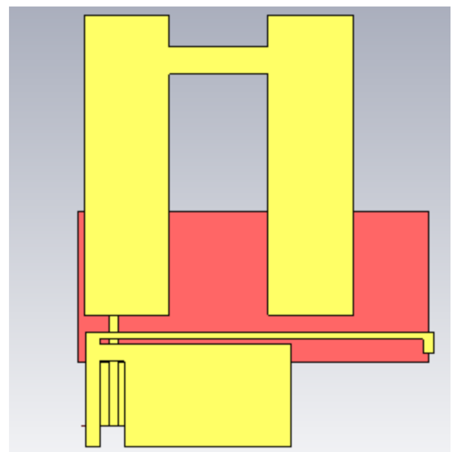

Fig. 4 – Front view of the overall design

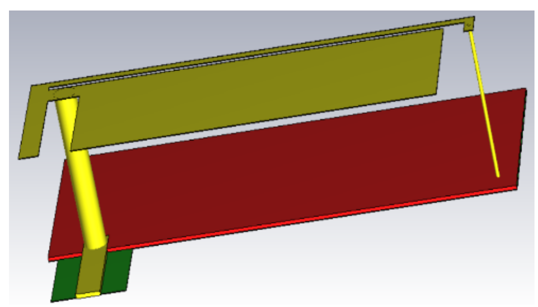

Fig. 5 – Overall view

PIFAs are valued for their compact size, low profile, and ability to provide good radiation efficiency at 2.45 GHz, even within the space constraints of modern devices. For a PIFA operating at this frequency, typical dimensions include a patch size of 20-30 mm and a substrate height of around 4-6 mm, depending on design requirements. The design of a PIFA also includes a shorting pin, which connects the radiating patch to the ground plane. This feature helps to reduce the overall size of the antenna by lowering the resonant frequency, making PIFA highly suitable for compact devices like smartphones, tablets, wearables, and IoT devices. The shorting pin and the feed pin work together to ensure that power is efficiently transferred to the antenna for radiation, thus maximizing its performance within the frequency band. The shorting pin, which connects the radiating patch to the ground, plays a key role in reducing the antenna's size by lowering its resonant frequency. The antenna is commonly used in Bluetooth devices such as headphones, smartwatches, and fitness trackers, where compactness and omnidirectional radiation are critical. In addition, PIFAs are also integrated into Wi-Fi devices and ZigBee-based IoT systems, offering reliable performance in short-range wireless communication. Overall, PIFAs operating at 2.45 GHz are essential in providing efficient and consistent wireless connectivity in modern electronic devices. The designed antenna is proposed by Bluetooth energy communication which is commonly used in modern devices at 2.45 GHz. Considering it is to be used for a wearable device, it must be small in size and resistant to mechanical and temperature variations. An optimized planar inverted-F antenna (PIFA) with parasitic element is used to broaden the antenna bandwidth. The parasitic element's end is shorted to reduce the patch size to 22 × 7.25 mm^2, making it suitable for wearable devices such as Smartwatches. Also, the ground layer of antenna allows it to radiate well externally while interfering minimum with the internal medium behind it. As a result, the reflection coefficient is not affected by the changes in the internal medium. The maximum gain of the proposed antenna is 9.42 dBi, and its impedance bandwidth ranges from 2.1-2.5 GHz. Finally, the antenna can be fabricated into a wearable electronic device.

Table 1 – Dimensions of the designed antenna

Parameter description	Parameter	Dimension (in mm)
Substrate	*Ls*	25
	Ws	10.8
	*Ws*1	1.3
	c	1.25
Ground	*Lg*	25
	Wg	10.8
	*Ls*1	5.95
	*Ws*1	1.3
	a	4
	b	4.5
Radiating Patch	*Lp*	22
	Wp	7.25
	Lf	6
	Wf	1.3
	Lpe	23.6
	Wpe	0.5
	d	0.3
	e	1
	f	1.7
	g	1.05
	h	6
Feeding pin	*R*	0.6
	*h*1	8.5
Shorting pin	*r*	0.1
	*h*2	8.5

3. RESULTS AND DISCUSSION

The suggested antenna operates between 2.25 GHz and 2.5 GHz. The S11 parameter ensures that the impedance spectrum is well-matched. Radiation gain is observed at 9.42 dBi. Theta 'Θ' and phi 'Φ' are spherical coordinates for co- and cross-polarizations that range from 0 to 360 degrees in the *E*-plane and 0 to 90 degrees in the *H*-plane. The Patch receives surface current from the feedline. The surface current flows along the radiating patch, ground plane, and shorting pin. Analysing current distribution is essential for understanding how the antenna radiates. Areas with high current densities often correspond to the regions of strong radiation, while areas with low current density may experience nulls in the radiation pattern. Uniform current distribution leads to improved radiation characteristics and gain. Fig. 6 shows the graph of reflection coefficient vs frequency, and it can be observed that the antenna is resonating at 2.45 GHz frequency.

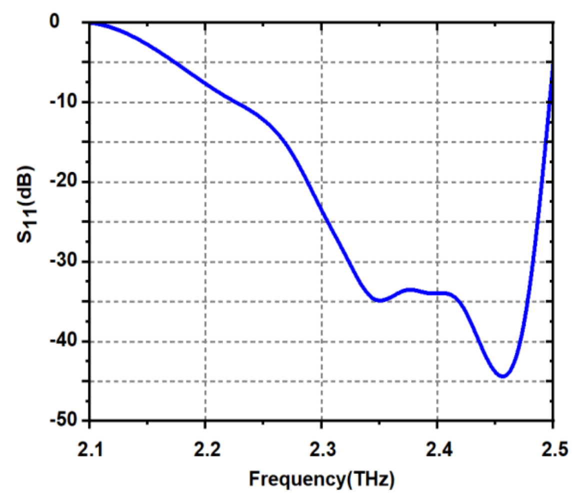

Fig. 6 – Reflection coefficient vs Freq

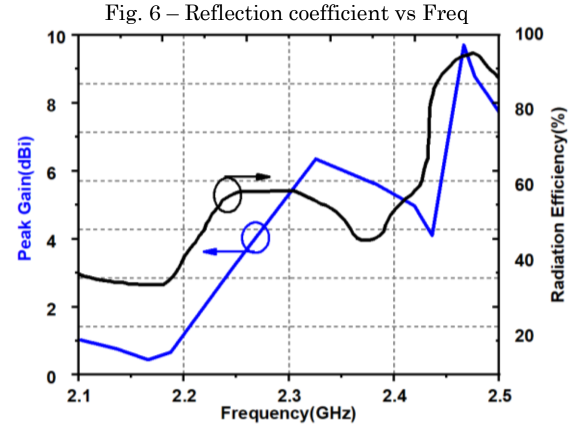

Fig. 7 – Maximum gain over frequency

Figure. 7 illustrates a graph that shows the performance of the proposed PIFA antenna in terms of gain and radiation efficiency. From the graph.7, it can be noted that a maximum of 9.42 dBi can be obtained at 2.45 GHz frequency with a radiation efficiency of 90 %.

4. CONCLUSION

The combination of two types of inverted-F antennas – one for low-SAR smartphone applications and one for wearable applications – is an exciting development in antenna design that could lead to size, efficiency, and performance gains. The 25 × 10.8 mm² dual coupling PIFA, which has a completely covered copper ground plane, proved to be very efficient and capable of reducing SAR, making it an ideal candidate for use in smartphone applications. This antenna attained a broad bandwidth of 2.35 to 2.45 GHz and a significant gains of 6.3 dBi and 9.42 dBi respectively. By taking the advantage of the improved *E*-field, *H*-field, and surface current resonant frequencies. Regardless of the user's head position or handling, the design effectively reduced SAR by dispersing source power in two directions and adjusting phase variation between the antennas. The precision and dependability of the antenna design were validated by the simulation results for Gain tradiation efficieny and reflection coefficient characteristics. There is a maximum gain of 9.42 dBi from the two designs implemented together. These developments guarantee improved performance, security, and dependability in contemporary communication equipment, positioning them to meet the needs of both present and emerging wireless technologies.

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Оптимізований подвійний зв'язок PIF антени для смартфонів та портативних пристроїв із низьким коефіцієнтом SAR

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PIF антена має ряд переваг, таких як компактні розміри, низький профіль та здатність забезпечувати хорошу ефективність випромінювання для бездротових застосувань. Запропонована PIF антена резонує на частоті 2,4 ГГц з кращою ефективністю випромінювання та коефіцієнтом посилення. Пристрій має розмір випромінювальної пластини 22 × 7,25 мм² та висоту підкладки 1,3 мм. Новим аспектом запропонованої конструкції є широкосмугова ширина та досягнення кращої продуктивності. Конструкція PIFA також включає короткий контакт, який з'єднує випромінювальну пластину із заземленою площиною. Ця особливість допомагає зменшити загальний розмір антени, знижуючи резонансну частоту, що робить PIFA придатним для компактних пристроїв, таких як смартфони, планшети, портативні пристрої та пристрої Інтернету речей. Короткий контакт та контакт живлення працюють разом, щоб забезпечити ефективну передачу енергії на антену для випромінювання, таким чином максимізуючи її продуктивність у смузі частот. Короткий контакт, який з'єднує випромінювальну пластину із землею, відіграє ключову роль у зменшенні розміру антени шляхом зниження її резонансної частоти. Для смартфонів подвійний зв'язок PIFA з розмірами 25 × 10,8 мм² та повністю покритою мідною заземлювальною площиною продемонстрував чудову ефективність та можливості зниження коефіцієнта поглинання коефіцієнта поглинання (SAR). Розроблена антена працюватиме на частотах від 2,35 до 2,45 ГГц відповідно.

Ключові слова: PIF антена, SAR, Портативне застосування,Резонансна частота.