PIFA Multi-layers for smart watch application in the 2.4 GHz for the Bluetooth Low Energy BLE

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Abstract

This paper presents a Planar Inverted-F Antenna (PIFA) design for a smartwatch application, optimized to operate on the 2.4 GHz Bluetooth frequency band, on the proximity of the human forearm. The PIFA antenna is mounted on the watchstrap that is used as the antenna substrate. The antenna is fed in a singular way, since a coplanar wave-guide (CPW) transmission line is used to excite the antenna. The antenna is integrated in the watchstrap, curved over the phantom forearm and simulated along with the watchcase. By a multi-layer substrate, half air half rubber we obtain a return loss of –20 dB is obtained at 2.4 GHz, and an efficiency of -5 dB, which represents a good efficiency taking into account the effect of the human forearm.

***Keywords*—PIFA antenna, on-body application, smartwatch, BLE.**

1. Introduction

In recent years, research into wearable antenna applications has gained a growing attention due to its potential applications in areas such as E-health systems, home care, security, and entertainment.

The antenna is to be lightweight, low cost, and maintenance-free, to meet the requirements of the application and the market. Considering the miniaturization and stable performance close to the human body, the planar inverted-F antenna (PIFA) can be considered a good candidate [1].

The structure proposed is a conventional PIFA optimized to operate at 2.4 GHz, conformed on the watchstrap, along with a CPW transmission line, that connects the antenna with the watchcase. The watchstrap is made of a flexible material, which will constitute the substrate on where the antenna is mounted.

The simulation take into account the curving effect of the antenna, the substrate used as the watchstrap, the watchcase, the feeding technic, and the human body effect, to have a more closer view to the behavior of the antenna in a real case user.

Finally, the antenna reflection coefficient, efficiency and the pattern radiation are evaluated with CST 2020, taking into account the whole watch structure in the presence of the human forearm phantom. A comparative table between the proposed antenna and other existing antenna will be presented as well.

2. Geometry of the antenna

The proposed structure is a Planar Inverted-F antenna, optimized to operate at 2.4 GHz band. The main advantage of using a PIFA is its reduced electric length and folded structure. Moreover, the impedance matching of the PIFA can be obtained by optimizing the space between feed and shorting pins. The main idea designing a PIFA is not to use any extra lumped components for matching network, and thus avoid any losses due to those elements [2]-[3].

Fig. 1 shows the geometry of the antenna. The dimensions of the antenna are summarized in Table I. Using two shorting pins instead of a shorting wall facilitates the connection of the feeding CPW transmission line, besides having an easy fabrication. A 50 Ω CPW line transmits the power from the watchcase to the antenna. Six shorting pins are placed on both sides of the CPW line to connect the ground plane of the CPW line with the antenna ground plane, as shown in Fig 1(a). The CPW has the dimensions Wcpw, and g. The CPW feeds the radiating plate at a distance fx from the shorted edge of the antenna. The substrate used is half rubber half air. The antenna element and CPW transmission line are made of cupper of thickness 0.35 µm. Fig.2 shows an overall view of the curved PIFA antenna fed by a CPW line.

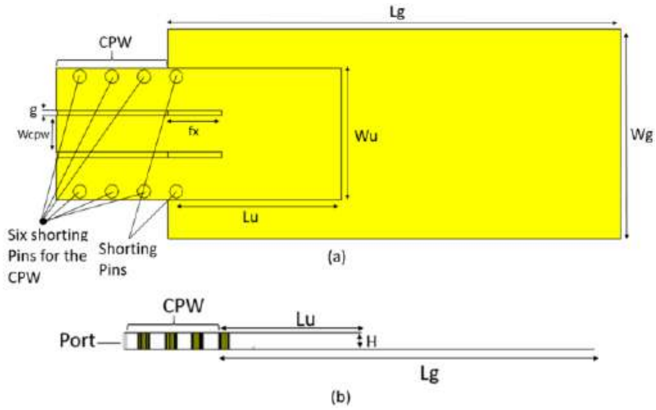

Figure 1: Geometry of the proposed PIFA antenna fed by a CPW transmission line (a) Top view and (b) Side view.

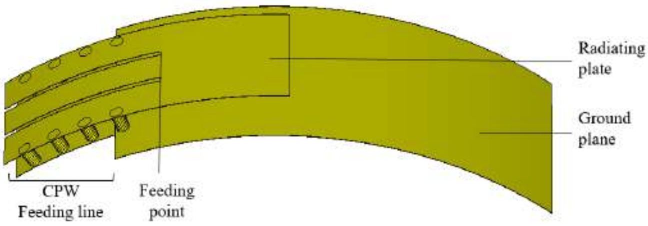

Figure 2: Geometry of the proposed PIFA antenna fed by a CPW transmission.

Table 1: Dimensions of the antenna and CPW (units in mm)

Lg	Wg	H	Lu	Wu	Wcpw	g	fx
45.3	18.97	1.84	16.2	11.97	3.3	0.5	4.85

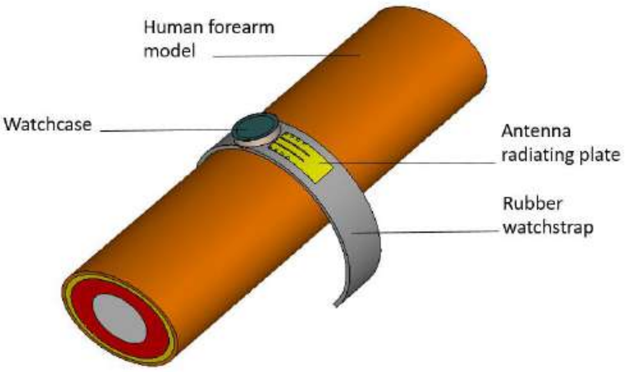

Figure 3: Human forearm phantom, with the PIFA antenna mounted on the rubber substrate of the watchcase.

Fig.3 shows the antenna mounted on the watch strap, modelled with a flexible substrate. The watch strap has standard dimensions: Ls=200 mm, Ws=20 mm and thickness Hs=1.84 mm. The substrate, which is the watchstrap, is made of rubber, with a dielectric constant of 3 and loss tangent 0.001. The watchcase is modelled by three elements: an external case made of polycarbonate dielectric constant of 2.9 and a loss tangent of 0.1, a battery made of PEC and a top cover made of glass. Fig.3 present the human forearm model used for this simulation, and table.2 the component. the human forearm phantom has four layers [4]: The skin, fat, muscle and bone.

3. Discussion

In this section, the proposed antenna, mounted on the watchstrap, along with the watchcase and the human forearm phantom, is simulated and evaluated.

3.1. Reflection coefficient

The antenna's reflection coefficient (S_{11}) simulated from 1 GHz to 4 GHz is depicted in Fig. 4. The reflection coefficient is -20.6 dB at the 2.4 GHz. The matching bandwidth for a -10 dB reference goes from 2.38 GHz to 2.43 GHz.

3.2. Radiation efficiency and total efficiency

The total efficiency (green curve) and radiation efficiency (red curve) are shown in Fig. 5. As observed, at 2.4 GHz, the total efficiency is -5.17 dB, and the radiation efficiency is -5 dB.

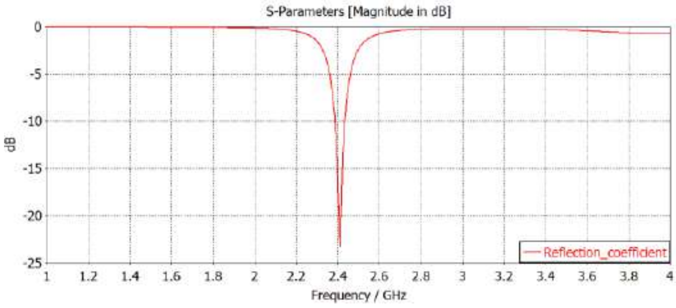

Figure 4: Simulated reflection coefficient of the proposed antenna integrated in the watch strap in the presence of the human forearm model.

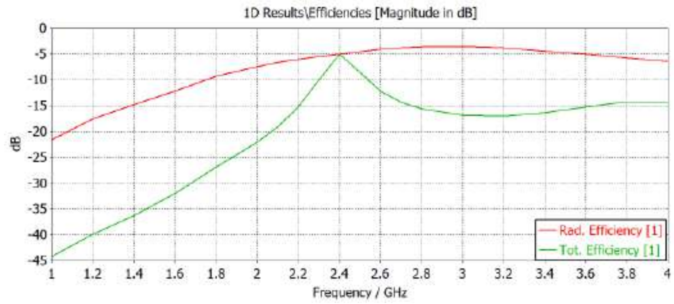

Figure 5: Simulated total efficiency (green curve) and radiation efficiency (red curve) of the proposed antenna considering the human forearm and the complete watch.

4. Conclusions

A compact PIFA antenna designed for smartwatch application, on the Bluetooth frequency band has been presented. The antenna is mounted on a rubber watchstrap to increase the available space inside the watch case. The effect of the human body has been taking into account and a realistic technique to feed the antenna using a CPW transmission line has been proposed. The simulated results confirm that the antenna is a good candidate for the smartwatch application. A prototype of the antenna will be fabricated to validate the simulated results and the Specific Absorption Rate (SAR) will be calculated.

Acknowledgements

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References

[1] G. Gao, C. Yang, B. Hu, R. Zhang and S. Wang, "A Wide-Bandwidth Wearable All-Textile PIFA With Dual Resonance Modes for 5 GHz WLAN Applications," in IEEE Transactions on Antennas and

Propagation, vol. 67, no. 6, pp. 4206-4211, June 2019, doi: 10.1109/TAP.2019.2905976.

[2] Wong Kin Lu. Planar antennas for wireless communication, John Wiley & Sons, New York, 2003.

[3] *David M. Pozar, Microwave Engineering. Hoboken, NJ :Wiley, 2012.*

[4] H. A. Damis, R. Mirzavand, H. Chung and P. Mousavi, "Flexible printed square loop antennas for wearable applications," *2016 17th International Symposium on Antenna Technology and Applied Electromagnetics (ANTEM)*, 2016, pp. 1-2, doi: 10.1109/ANTEM.2016.7550212.

[5] R S. Lin, Y. Lin, J. Peng and Y. Tuan, "Microstrip antennas for smart watch," *2016 IEEE 5th Asia-Pacific Conference on Antennas and Propagation (APCAP)*, 2016, pp. 109-110, doi: 10.1109/APCAP.2016.7843122.

[6] K. Zhao, Z. Ying and S. He, "Antenna designs of smart watch for cellular communications by using metal belt," *2015 9th European Conference on Antennas and Propagation (EuCAP)*, 2015, pp. 1-5.

A. Shafqat, F. A. Tahir and H. M. Cheema, "A Compact Uniplanar Tri-band Antenna for Wearable Smart Watches," *2018 18th International Symposium on Antenna Technology and Applied Electromagnetics (ANTEM)*, 2018, pp. 1-3, doi: 10.1109/ANTEM.2018.8