PIFA antenna for smart watch application in the 2.4 GHz band

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***Abstract— 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. 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, Bluetooth.**

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 smart watch is a promising wearable device for mobile communication. Its rapid growing has attracted huge attentions from industries and public. However, due to the limited space within the wearable device, and its proximity to the human body, the design of an operating antenna at the Bluetooth band presents various challenges.

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].

Typically, commercial smart watches integrate the antenna inside the watchcase, which makes the antenna highly influenced by the presence of the battery, the screen and the PCB circuitry. In this paper, we propose to integrate the antenna in the watchstrap, in order to increase the available space and decrease the effect of the watch components.

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.

Finally, the antenna reflection coefficient and efficiency are evaluated with CST 2020, taking into account the whole watch structure in the presence of the body.

I. Geometry of the Antenna

The proposed antenna 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, of length Lg=45.3 mm, width Wg=18.97 mm and the height H=1.84 mm. The length of the upper part is Lu=16.2mm and width Wu =11.97mm. Two shorting pins located at the antenna edge connect the upper radiating plate, with the bottom plate. Using two shorting pins instead of a shorting wall facilitate the connection of the feeding CPW transmission line, besides having an easy fabrication. The 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=3.3 mm, and g=0.5 mm. The CPW feeds the radiating plate at a distance of fx=4.85 mm from the shorted edge of the antenna. The substrate used is rubber. The antenna element and CPW transmission line are made of cupper of a thickness of 0.35 µm.

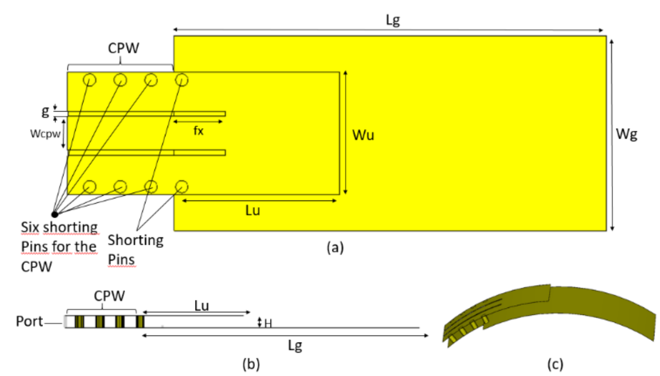

Fig. 1. Geometry of the proposed PIFA antenna fed by a CPW transmission line (a) Top view, (b) Side view and (c) General view of the curved antenna.

Fig. 2 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. Three elements are considered to model the watch case: a external case made of polycarbonate, a battery made of PEC and a top cover made of glass. As can be seen in Fig. 2, the human forearm phantom has four layers [4]: skin with Ɛr=38.007 and loss tangent 0.28262, fat with Ɛr=5.2801 and loss tangent 0.14524, muscle with Ɛr=52.729 and loss tangent 1.7388, and bone with Ɛr=18.548 and loss tangent 0.80517.

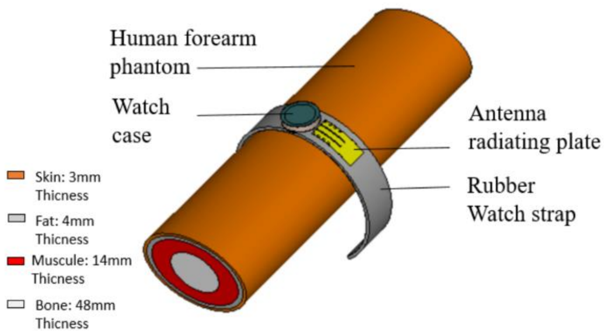

Fig. 2. Human forearm phantom, with the PIFA antenna mounted on the rubber substrate of the watch case.

II. Results and Discution

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

A. *Reflection coefficient*

The antenna's reflection coefficient (S_{11}) simulated from 1 GHz to 4 GHz is depicted in Fig. 3. 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.

B. *Radiation efficiency and total efficiency*

The total efficiency (green curve) and radiation efficiency (red curve) are shown in Fig. 4. As observed, at 2.4 GHz, the total efficiency is -5.17 dB, and the radiation efficiency is -5 dB.

C. *Radiation pattern*

The simulated radiation pattern at 2.4 GHz is shown in Fig. 5. As can be observed the radiation is mainly focused in the broadside direction as desired, opposite to the forearm.

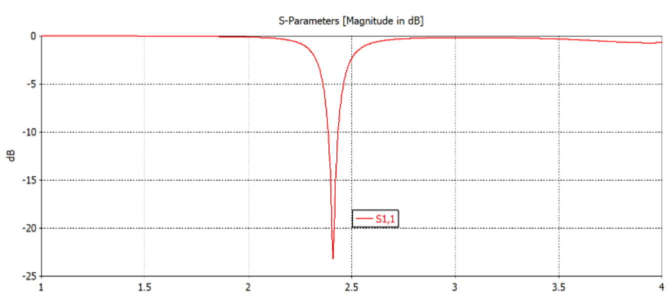

Fig. 3. Simulated reflection coeficient of the antenna described in Fig. 2.

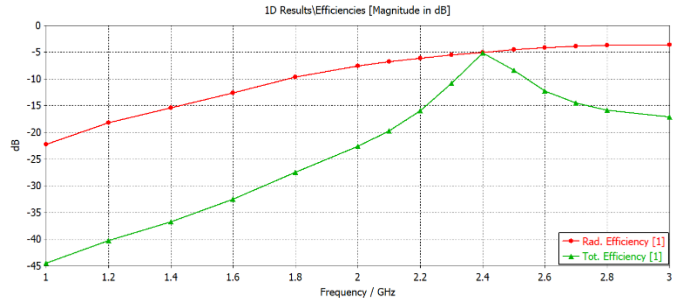

Fig. 4. Simulated total efficiency (green curve) and radiation efficiency (red curve) of the proposed antenna considering the human forearm and the complete watch.

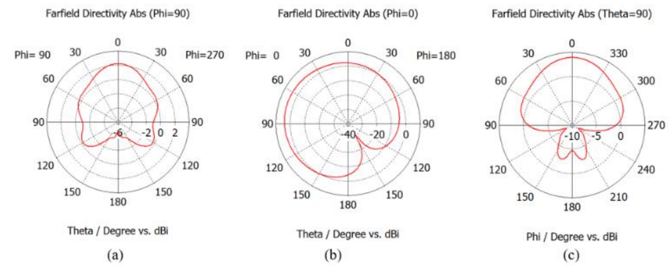

Fig. 5. Radiation pattern of the proposed antenna at 2.4 GHz: (a) Phi= 90º, (b) Phi=0º and (c) Theta=90º.

III. Conclusion

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.

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