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Compact Patch Antenna for Wearable Health Monitoring Applications

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Abstract: ***This paper presents a design study of a compact antenna for the wearable devices. Bluetooth Low Energy (BLE)/2.4 GHz frequency has been considered for the wearable device and communications. The proposed antenna is designed on 0.2 mm thick FR4 substrate with ϵr = 4.4 and tanδ= 0.02. The proposed antenna along with the 80 MHz bandwidth centered at 2.45 GHz results an expected omnidirectional radiation performance in horizontal plane and its suitability to be installed inside the wearable device above to the sensors integrated PCB circuitry on the top cover of the smart wearables. The antenna structure is a compact patch antenna configuration with the inset feeding structure and shorting at another end. With the aim at the usages in the abovementioned scenario (inside the device along with the circuit PCB considerations), the flexibility and the performance of the antenna element is well suitable for the wearable devices.***

Keywords: Bluetooth low energy, Patch antenna, Omnidirectional radiation, Wearable communications

1. Introduction

The Bluetooth Low Energy (BLE) is a type of wireless communication technology designed especially for short-range communications. This technology operates in the same spectrum range (the 2.400–2.4835 GHz ISM band) as classic Bluetooth technology but uses a different set of channels for the communications [1]. Antenna is the main component for the radiation in communication systems. Related works on the antenna design technologies has been reported in the literature for communications [2-3]. However, the antenna required for the wearable devices is needed to be designed and investigated well in the limited space available inside the device for the respective communications schemes [4-5]. This paper presents an antenna design structure for the wearable device for BLE communications which is applied on the wearable watch device[5]. In this work the antenna design scenario has been considered for the smart watch type wearable. Fig.1 shows the wearable device on the wrist of human, like a wrist watch type device. In general the device is composed of various components inside it. The battery area lies at the bottom and the PCB circuitry area above the battery. Since the space between the PCB circuit area and the upper lid of the device has some available space, therefore the antenna can be attached on the bottom side of the upperlid of the device. In this paper, the antenna design for the required band and installation of the antenna on the upper lid of the device has been considered. Further the device has been placed on various locations on the human body such as on wrist, inside the front pocket and on back side at upper waist position to test the received signal strength (RSSI) by the receiver at certain points and discussed in detail. Section II describes the proposed antenna design parameters and the performance in terms of the S-parameters with and without tissue and suitability of the device to work on the human body and section III describes the detailed measurement results on the human body at various locations. The conclusion is made insection IV.

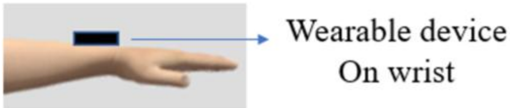

Figure 1: Wearable device consideration on the wrist

2. Proposed Antenna Design

To design the antenna for wearable devices, the size consideration of the antenna becomes necessary part of the investigation. The antenna location is decided inside the wearable device to radiate well in the surrounding directions while minimizing the radiations into the body tissue.

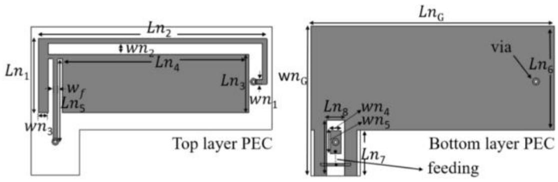

Figure 2: Antenna for wearable device: top layer and bottom layer.

TABLE I
DIMENSIONS FOR THE PROPOSED ANTENNA (UNITS IN MM)

Variable	Value	Variable	Value	Variable	Value
Ln_g	25.0	Ln_4	19.3	wn_1	0.5
Wn_g	15.5	Ln_5	8.5	wn_2	1.1
Ln_1	7.8	Ln_6	10.8	wn_3	1.0
Ln_2	23.8	Ln_7	4.8	wn_4	1.1
Ln_3	6.1	Ln_8	1.9	wn_5	2.4

The proposed antenna can be seen in Fig. 2. In contrast, the proposed antenna has a complete ground plane on the bottom layer. The substrate material FR-4 with the thickness of 1.6 mm has been used for the proposed antenna. The antenna is designed following the concept of the Planar Inverted-F antenna (PIFA), which reduces the antenna size by having a shorting pin near the feeding pin.

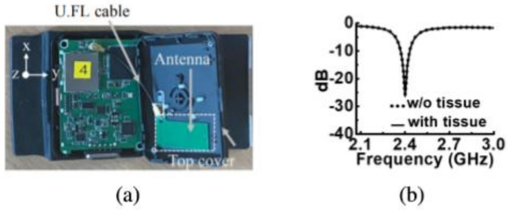

Figure 3: (a) Antenna installation inside the watch-type wearable device. (b) S-parameters measurement

The U.FL port assembly has been made with the conductor strips which is attached on the ground plane and connected to the main element through the via connection. The adoption of the standardized U.FL port not only makes the assembly of the antenna to the system convenient but also makes the antenna performance highly reproducible by removing uncertainties in how the antenna should be soldered to a cable. Also, the shorting pin is moved from the feeding edge along the patch direction by *Ln1* and further moved around the patch by *Ln2* with the separation of *wn3*. All the design parameters shown in Fig. 2(b) are carefully optimized to yield a good matching to 50 Ω at the carrier frequency. After the optimization, the dimensions of the antenna are summarized in Table I. The S-parameters are shown in Fig.3. The proposed antenna shows a stable S-parameter regardless of whether the device is on or off the tissue in Fig. 5(b). It can be inferred that the performance of the proposed antenna should be rarely affected by the user environment. The S11≤-6 dB impedance bandwidth was measured to be 80 MHz from 2.4-2.48 GHz with the proposed antenna on tissue.

3. On Body Measurements

The antenna is installed on the wearable device and placed on the various locations on the body as can be seen in Fig.4. The reader is located at the distance of 120 cm from the human body and later the human body with the device is rotated 360 degrees to test the various RSSI levels. The RSSI levels are presented in Fig.5.

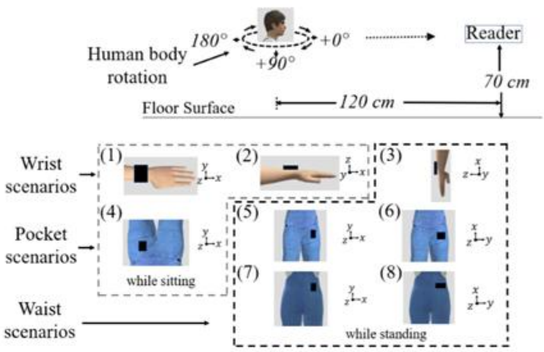

Figure 4: Antenna performance measurement scenario.

It is observed that while the wearable device is kept on the wrist and front pocket (sitting) similar values can be obtained with the maximum at around *0◦* directions. Situation 2 shows the device is on wrist but facing the reader and that becomes similar to the situation in 5. Both are presented in Fig.5 (b). It is observed that in case of the wrist the maximum is obtained at *0◦* and around *90◦* in case of the pocket scenario. This is because the device and reader are not in the light of sight directions. Fig. 5(c) shows the standing scenario of the human being and in attention position while wearing the device and the device is placed in the pocket (scenario 3 and 6). The RSSI for these cases has been plotted and observed that the maximum is around *90◦* directions due to the non-line of sight scenario. Fig.5(d) shows the measurement of the device located on the upper waist at the back side. and shows that the maximums are obtained around *−90◦* directions. The device's Tx power was set to -12 dBm and the minimum RSSI of -90 dbm was observed at certain points. However, if the Tx power is improved the RSSI will increase for all positions. These RSSI values show that the device can communicate well on body communications with the minimum -12 dBm power levels.

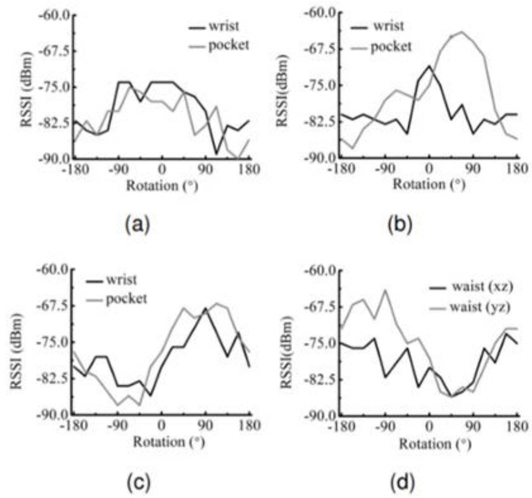

Figure 5: RSSI Measurements (a)Situations 1 and 4, (b) Situations 2 and 5, (c) Situations 3 and 6, (d) Situations 7 and 8

4. Conclusions

In this work an antenna design study has been carried out for BLE commutations. The proposed antenna was fabricated and installed in the wearable device for BLE communications. The proposed antenna shows negligible change while kept on tissue. The reason for the better working ability of the proposed antenna is the inclusion of a complete ground plane beneath the main radiation patch. The above study is useful for the small wearable devices and further size reduction of the antenna with improved performance can be done in the similar way which can be used for the communications for the other bands of interest.

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