A Novel Small-Size Quad Band Internal PIFA for GPS L1/Bluetooth/LTE2500/WiMAX/HIPERLAN1 Applications

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Abstract

A novel quad band planar inverted F-antenna along with an added resonating copper arm working in GPS L1/Bluetooth/LTE2500/WiMAX/HIPERLAN1 is presented. The proposed antenna occupies a volume of 25 x 10 x 5.8 mm^3 over the mobile circuit board. Parametric investigations of some important parameters are carried out to observe their effect on antenna performance. The proposed antenna is presented with radiation patterns in the principle planes along with peak realized gain.

Keywords: internal mobile antenna, planar inverted F-antenna, quad band antenna, resonating arm.

1. Introduction

There is a great demand of internal antennas suitable for mobile devices covering a wide range of applications. PIFA (Planar inverted F-antenna) is a suitable candidate to meet this requirement of mobile devices. Several dual band[1-4] and multiband[5-7] PIFA structures have been developed to support various applications. For better mobile broadband and multimedia services LTE (Long term evolution) is a very attractive service of fourth generation of mobile communication.[8] Inclusion of GPS (Global Positioning System) service in the mobile phones that support the user in location finding and tracking application is also required. GPS works in L1 (1.565-1.585 GHz) band for civilian purpose and in L2 (1.227-1.575 GHz) band for military purposes.[9]

Because of the strict space availability within the mobile phone, it is a challenge to accommodate antennas covering large number of applications. To meet this requirement of mobile devices, a quad band antenna covering GPS L1 (1.565-1.585 GHz), Bluetooth/Wi-Fi (2.4-2.484 GHz), LTE2500 (2.5-2.57 GHz for uplink, 2.62-2.69 GHz for downlink), WiMAX (3.3-3.4 GHz), and HIPERLAN1(5.15-5.35 GHz) bands is presented in this paper. The proposed antenna occupies a volume of 25 x 10 x 5.8 mm^3 above the mobile circuit board and, is suitable to be fabricated at low cost and attractive for slim mobile phones. Antenna design concept is presented in section II. Simulated return loss characteristics of the proposed antenna along with effect of various parameters on antenna performance, radiation pattern, and peak realized gain are presented in section III of this paper.

2. Antenna Configuration

In the proposed design the antenna is mounted on the top corner of the mobile circuit board of size 100 X 60

mm^2 at a height of 5 mm. The chosen dimension of the circuit board is suitable for the most of the practical mobile phones. The Antenna is short circuited through a shorting strip of width 5 mm. Configuration of the proposed antenna is shown in Fig. 1. The side views of the proposed antenna in XZ plane and YZ plane are shown in Fig 2(a) and 2(b), respectively. The antenna is basically designed for 1.575 GHz using the Eq. (1),

$$f = \frac{c}{4(L+W)} \quad (1)$$

Where, L and W are the length and width of the rectangular PIFA.

The dimensions comes out from the equation are large to be integrated in the small space of mobile phone. Thus we fold the structure and etched it over the FR4 substrate (dielectric constant = 4.4) of 0.8 mm thickness. The unfolded view of the patch is given in Fig. 3 (a). The top patch of the radiator is fed by a coaxial cable. Fed position is optimized to get the better impedance matching. The patch gives the desired resonance at 1.575 GHz along with the one higher order mode centered at 3.27 GHz. Another higher order mode is present at 5.2 GHz, but with a VSWR not better than 3:1. Thus to improve its matching a rectangular slot of dimension 12.3 x 1 mm^2 is cut at the top surface of the substrate. Now for further introduction of a resonance centered at the center frequency of LTE2500 band, a resonating arm is introduced into the structure which consists of a rectangular vertical strip and inverted L-shaped horizontal strip. The vertical strip provides the inductive effect and is connected to the edge of the main radiator. The unfolded view of this arm is shown in Fig. 3 (b).

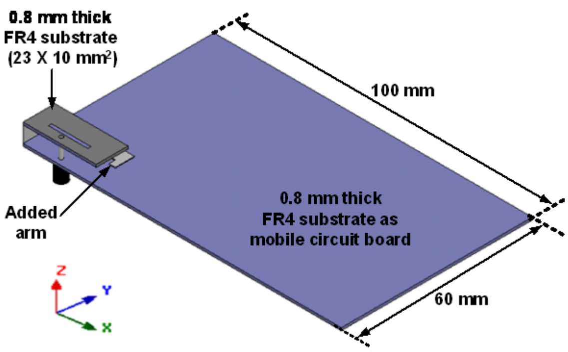


Fig. 1. Configuration of the proposed antenna.

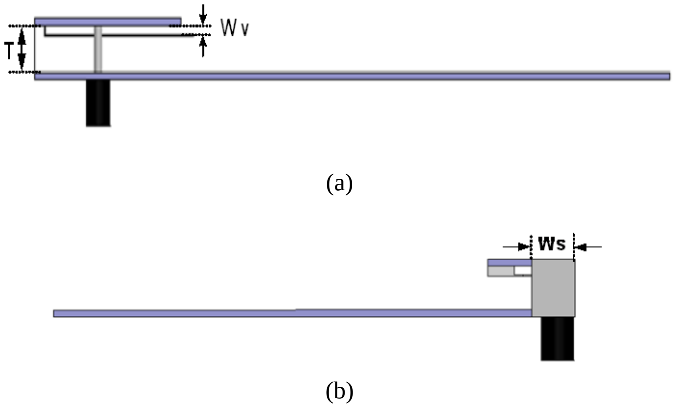


Fig. 2. Side view of the proposed antenna in (a) XZ plane, (b) YZ plane: T = 5 mm, Wv = 1 mm, Ws = 5 mm.

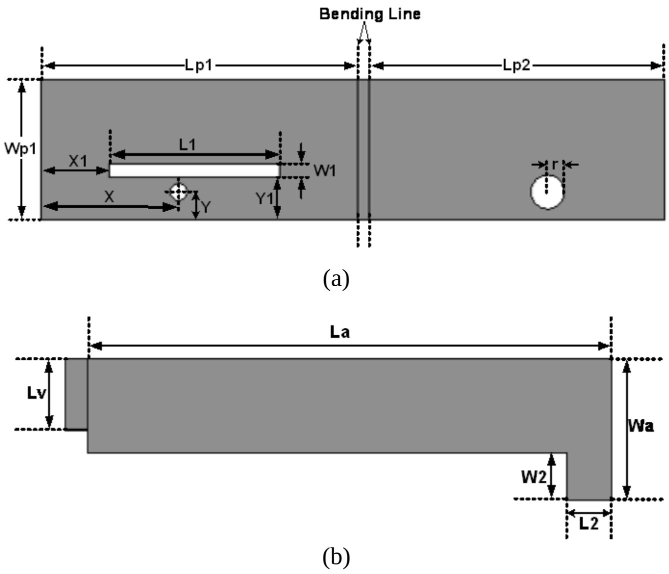


Fig. 3. Unfolded view of (a) patch, (b) added arm: Lp1 = 23 mm, Wp1 = 10 mm, Lp2 = 21.5 mm, X = 10 mm, Y = 2 mm, L1 = 12.3 mm, W1 = 1 mm, X1 = 5 mm, Y1 = 3 mm, r = 1.2 mm, La = 23.5 mm, Wa = 6 mm, Lv = 3 mm, L2 = 2 mm, W2 = 2 mm.

3. Results and Discussion

The proposed antenna is simulated using Ansoft's HFSS.[10] Fig. 4 shows the return loss characteristic of the proposed antenna. It is clear from the figure that impedance matching in the desired bands are better than -6 dB return loss which is generally used design specification for practical internal antennas used in mobile devices.

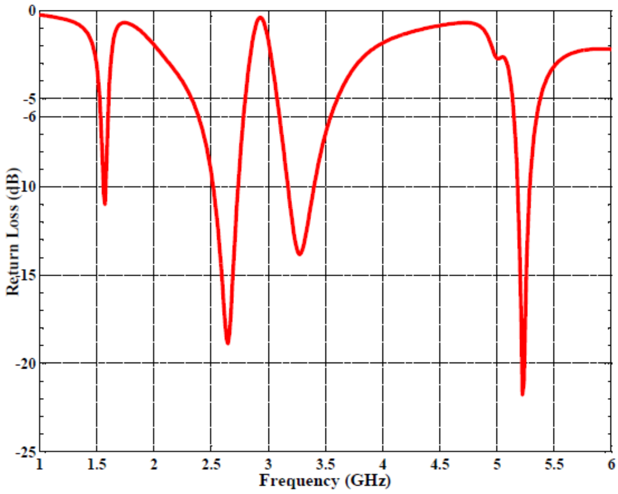


Fig. 4. Simulated return loss characteristics of the proposed antenna.

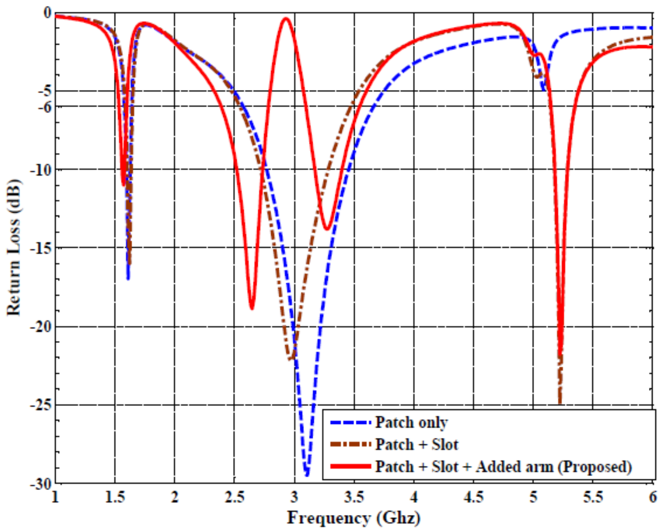


Fig. 5. Comparison of simulated return loss for patch only structure, structure having patch along with slot and proposed antenna.

Fig. 5 analyzes the antenna design concept by comparing the simulated return loss characteristics of the proposed antenna in absence of slot and added arm, in absence of added arm only and of the proposed antenna. It is seen that in the absence of slot and added arm, quarter wavelength resonant mode is excited at 1.575 GHz along with one higher order mode at 3.27 GHz and another higher order mode appears at 5.1 GHz, however the impedance matching is not good at 5.1 GHz resonant frequency. Further, this can be improved by cutting a narrow slot of proper dimension on the patch. It is interestingly noted that the frequency band 2.57-3.45 GHz is partially utilized by some of the applications of mobile communication. Therefore, it is decided to convert into dual band characteristics for the better utilization of aforesaid band. Hence, another quarter wavelength resonating arm is connected with the folded patch (Fig. 2(a)).

The effect of varying the width ‘Wv’ of vertical inductive strip of added arm is shown in Fig. 6. It is observed that the increase in ‘Wv’ is shifting the resonant frequency of 1.575 GHz and 2.65 GHz mode towards the lower frequency side while keeping the resonant frequency of other two modes unchanged. The reason of such a shifting in frequency is that the increase in ‘Wv’ is increasing the inductance and simultaneously increasing the capacitance of the horizontal part of added arm by decreasing the gap between the horizontal part and system ground plane.

Fig. 7 shows the effect of varying the slot length ‘L1’ on the return loss characteristics of the proposed antenna. It is observed that the variation in slot length is changing the performance of the antenna at 5.2 GHz mode while keeping the antenna performance in other modes remains constant. The optimized value of ‘L1’ is 12.3 mm.

Fig. 8 is shows the effect of varying the length ‘La’ of the added arm. It is seen that increase in length is shifting the resonant frequency of 2.65 GHz mode towards lower frequency side. This behaviour is due to the fact that increase in length is increasing the overlapping area of the added arm and the ground plane. This increase in area is responsible for the increase in capacitance and hence decreases the resonant frequency. The optimized value of ‘La’ is 23.5 mm.

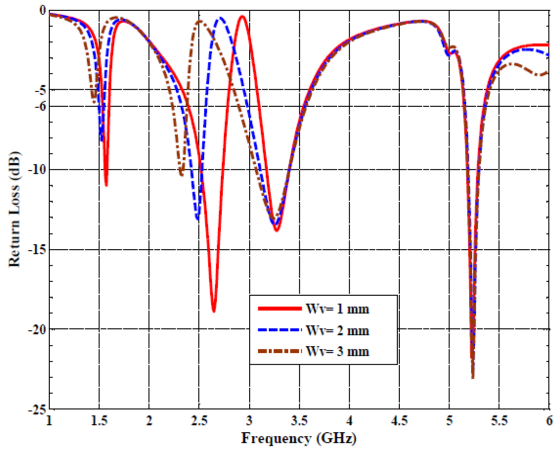


Fig. 6. Effect of variation of ‘Wv’ on the return loss characteristics of the proposed antenna.

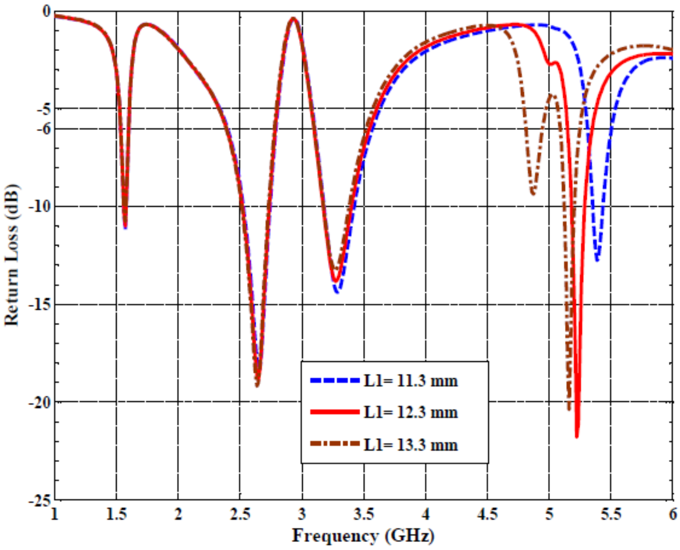


Fig. 7. Simulated return loss characteristics of the proposed antenna by varying ‘L1’.

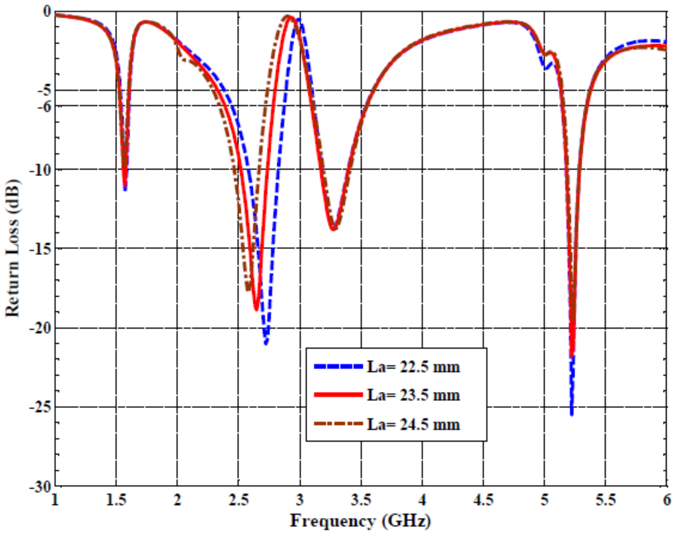
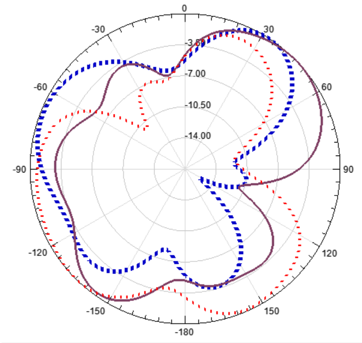
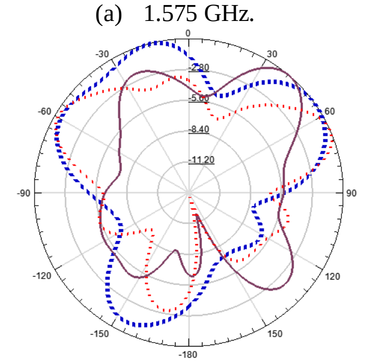


Fig. 8. Effect of variation of ‘La’ on the return loss characteristics of the proposed antenna.

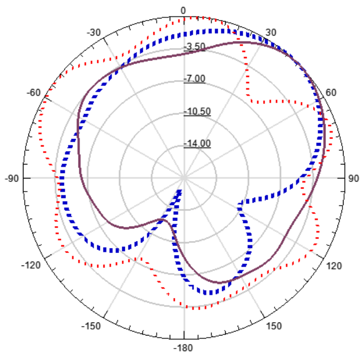
The simulated radiation patterns at 1.575 GHz, 2.5 GHz, 3.35 GHz, and 5.25 GHz for XZ, YZ and XY planes are plotted in Fig. 9. It is observed that the proposed antenna having almost omni-directional radiation pattern.



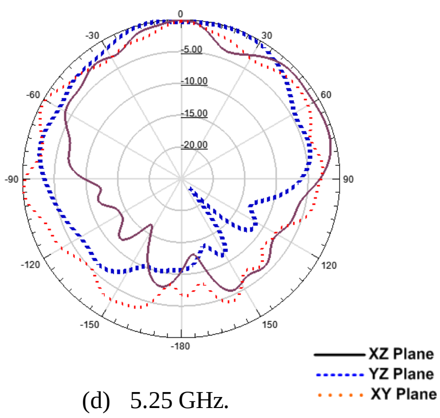
(a) 1.575 GHz.



(b) 2.5 GHz



(c) 3.35 GHz.



(d) 5.25 GHz.

Fig. 9. Simulated radiation pattern of the proposed antenna,

The peak realized gain at 1.575 GHz, 2.5 GHz, 3.35 GHz and 5.25 GHz is 5.72 dB, 5.11 dB, 4.39 dB and 3.95 dB, respectively. The value of gain is also seen at all other desired frequencies and it comes sufficient for practical mobile purpose.

4. Conclusion

A novel quad band antenna covering GPS L1/Bluetooth/LTE2500/WiMAX/HIPERLAN1 bands for mobile phones has been presented. The antenna occupies a very small volume of 25 x 10 x 5.8 mm^3 over the mobile circuit board. Good radiation patterns in the principle planes and sufficient gain has been obtained from the proposed antenna.

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