PIFA with Multi-Layered Structure for Bandwidth Enhancement

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Abstract

A bandwidth-enhanced planar inverted-F antenna (PIFA) using multi-layered PCB process is presented. The bandwidth of the proposed antenna is about 9.45% at 2.400 GHz. While the area of the antenna is decreased using L-shaped metallic patches, the thickness of the substrate is about 50% of that of the traditional PIFAs with same antenna area

I. INTRODUCTION

With the rapid development of wireless communications, portable wireless device has become more complex, the antenna space on the circuit board was limited and the antenna had height restrictions, hence a compact antenna without ground clearance was demanded recent years. The planar inverted-F antenna (PIFA) is popular for wireless communications because of its low profile, simple design, low cost, and convenient fabrication. It is well known that the bandwidth of the PIFAs is proportioned to the substrate thickness [1]-[2]. Thus, many PIFAs are often fabricated on thick substrates. This letter proposes a new structure with multi-layers PCB process to broaden the planar inverted-F antenna bandwidth under the same antenna area. The proposed antenna has been realized and measured, the simulation results obtained through High Frequency Structure Simulator (HFSS) [5], and is validated by measurements.

II. ANTENNA DESIGN

As shown in Fig. 1(a), the antenna is implemented on a finite dielectric slab ($\varepsilon^{r} = 4.4$). The dielectric is later mounted on a test substrate ($\varepsilon^{r} = 4.4$), as seen in Fig. 1(b), for which the dimension of printed-circuit board (PCB) for general handset device is applied. The side view of the mounted antenna in Fig. 1(c) depicts the multi-layered structure. Four metallic layers are applied in the design. The radiating portion of the antenna is formed using the top two layers, while the feeding network, mainly 50Ω microstrip, are formed using bottom two layers in the test substrate. There are also two vias which connect antenna to the microstrip and ground, respectively.

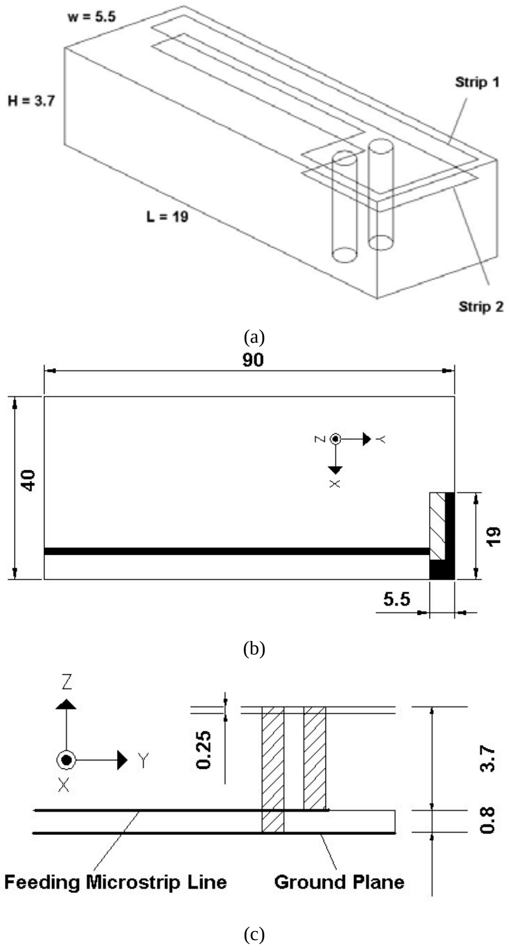

Fig. 1. (a) 3-D view of proposed PIFA with height H. (b) Antenna installation and test board. (c) side view of the antenna.

The dimension of the dielectric slab is (LxWxH) 19x5.5x3.7 mm^3, which is too small for traditional PIFA composed mainly a quarter-wavelength rectangular patch at 2.4GHz. To provide sufficient electrical length for the electric current on the antenna, an L-shaped patch, shown in Fig. 2(a), is applied. More complex shapes, such as meandered strips, are not considered due to lower antenna efficiency and possibly narrower frequency bandwidth. Two L-shaped patches are stacked together to obtained desired bandwidth performance. The distance of these two patches is set to be 0.25 mm to achieve 9.45% bandwidth. Most of the stacked PIFAs[3] use separated grounding and feeding straps for each different patches. In the proposed design, both patches share the same grounding and feeding vias. One via connects both patches to 50 ohm microstrip line, and other to the ground of test substrate. Unlike most PIFAs, the proposed design does not place the grounding via strictly on the edge. Moving the grounding via under the patches gives more freedom to matching-network design. Both vias introduce an inductance at the input of the antenna. Tuning the value of the inductance by adjusting the position of the vias, the impedance match at 2.4 GHz is obtained.

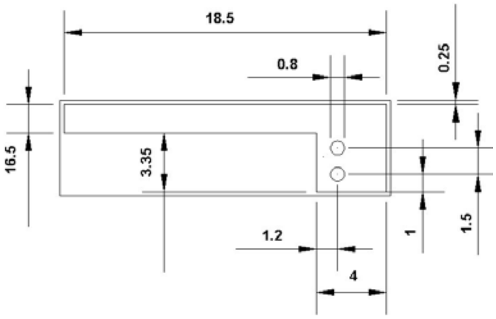

Fig. 2. The geometry of the proposed PIFA.

Figure 3 shows the simulated results of return loss for the proposed antenna (stacked L-patches) and traditional PIFAs (Single L-patch) with substrate thickness H=7.4 mm. With 3.7 mm substrate thickness the proposed antenna provides 9.45% -10dB return-loss bandwidth. The bandwidth of single-patch PIFAs with thickness H=7.4mm is 7.8%. Therefore, even with half substrate thickness, the proposed antenna still has better bandwidth performance.

III. Results

The return loss of the antenna is measured using Agilent E5071B vector network analyzer with SOLT calibration procedure. In Fig. 4, it is found that the simulated and measured return losses are in good agreement, except the 0.1 GHz shift of the center frequency due to the possible fabrication error. Fig. 5 shows the measured radiation patterns at 2.4 GHz generally, on X–Y and X-Z planes. In the antenna frequency band 2.2 ~ 2.5 GHz, the antenna gain (dBi) ranges for 1.9 ~ 0.35 and 1.68 ~ 2.33, on X–Y and X-Z planes, respectively. Thus, not only the proposed antenna has wide bandwidth in return loss, it also has wide bandwidth in antenna gain.

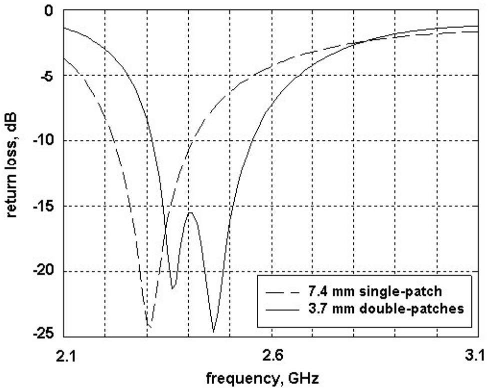

Fig. 3. Simulation results of traditional PIFA with antenna height H=7.4 mm and the proposed PIFA with H=3.7mm.

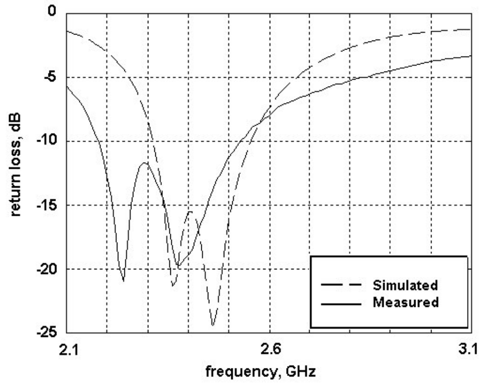

Fig. 4. Measured and simulated return loss of proposed PIFA

IV. Conclusions

A compact bandwidth-enhanced PIFA at 2.4 GHz has been presented in this paper. The volume (LxWxH) of the proposed antenna is 19x5.5.3.7 mm³. It provides better –10dB return loss bandwidth (9.45%) than the traditional PIFA with double antenna thickness. The measurement results indicate that the fabricated antenna exhibits good return-loss bandwidth and well radiation performance on a portable handset device.

Acknowledgment

The authors would like to thank Walsin Technology Corporation for the assistance to antenna fabrication.

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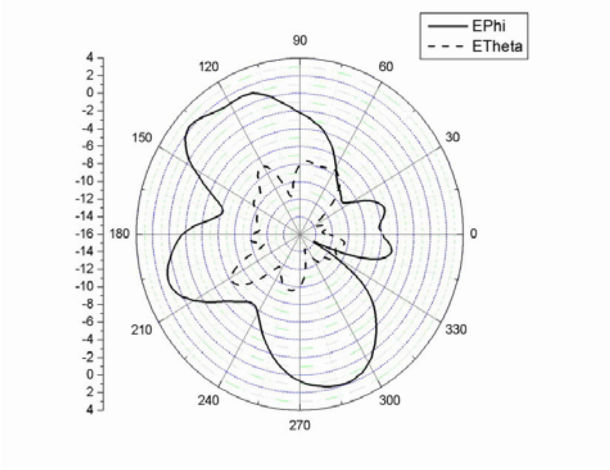
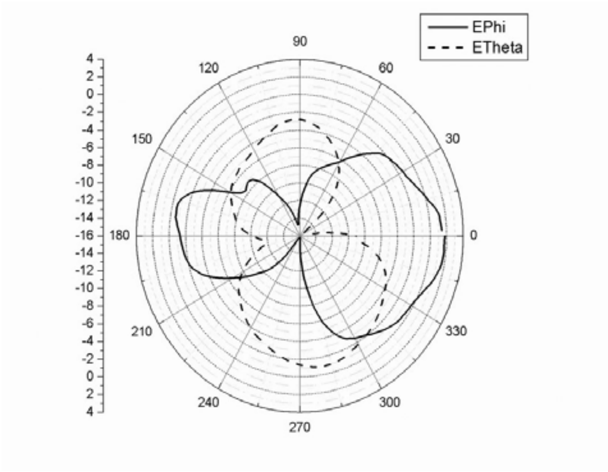


(a)



(b)

Fig. 5. Measured radiation pattern at 2.4 GHz. (a)X-Y cut. (b) X-Z cut.