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A Triple Band Inverted-F Antenna with Two Hybrid Shorting Strips For the Tablet Device

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Abstract:

A triple band inverted-f antenna with inductive and capacitive shorting strips placed close to antenna's capacitive feeding strip can provide three operating bands (Two wide operating regions covered from 860Mhz-1250Mhz and 1550Mhz-2800Mhz ,One narrow operating band of 3250Mhz-3550Mhz) in mobile phone devices. The combination of inductor L1 and bent plate act as helix loaded patch antenna to provide low band of operation, rectangular bar with gap coupled capacitor shorting act as patch antenna to provide high band of operations with minimum affects on low band of operation. The combination of inductor L2 and capacitor Cf acts as a matching circuit and also provide wide band of operation's in all three regions. The antenna can also be placed in a clearance region of 10 x 35 mm^2 inside the mobile phone device such as smart phone. Details of proposed antenna are presented.

Key words: Triple band antenna, 4G patch antenna, smart phone antenna and stacked antenna

Introduction

With rapid growth of personal communication services, the development of compact and small size antennas, for multiband operation, has become a fundamental requirement in antenna design. As the touch screen becomes larger and larger in the mobile handsets, the clearance area left for antenna is becoming smaller and smaller. Accordingly, the mutual coupling between the radiating elements and the ground plane is increased, which leads to an higher quality factor Q and brings more complex challenges to obtain wideband antennas. In this case inverted–F antenna is considered as promising antenna, since its radiative performances are quite independent from the size of clearance area on the ground plane. The inverted-F antenna mainly comprises a radiating arm, a feeding strip, and a shorting strip. Such antennas, however, generally provide insufficient bandwidths to cover the desired operating bands for the modern smart phone devices.

To achieve the dual-wideband operation, some useful bandwidth-enhancement for the inverted-F antenna has been reported recently [1]. Multiple feeding techniques for PIFA antenna are also proposed [2] for solving problem of low clearance area in dual band of operation. Inverted-F antenna with dual feeding with passive elements produces the mobile phone application up to 3G [3].

Recently, the concept of using passive switching circuits to achieve similar switchable functions as the active switching circuit has been applied for LTE/WWAN mobile handset antenna [4].To provide multiple bands in mobile phone with simple structure of radiating metal portion with multiple resonant paths and branches [5]-[9] are used in small clearance areas. In addition, the antenna with active elements is required for tuning the bands [10]-[15].

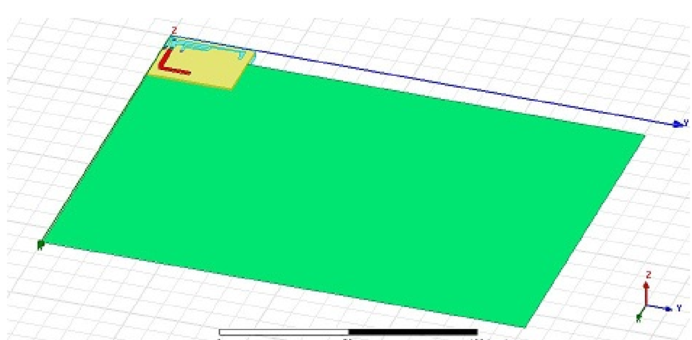

Figure 1: Proposed Triple band inverted-F antenna.(green- ground plane , yellow-substrate, sky blue-proposed antenna red-feeding strip)

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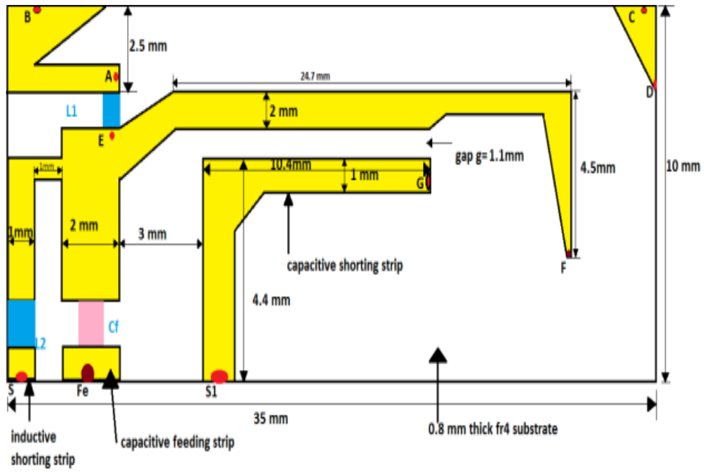


Figure 2: proposed triple band F antenna with substrate and radiating plates (L1= 9.1nH, L2= 9.3nH, Cf= 3pF)

In this paper, the design concept of using passive switching circuits is applied to a antenna design with inductive and capacitive shorting strips and capacitive feeding for smart phone device for 4G network operation. In the proposed design, the antenna occupies a volume of 3.8 x 10 x 35 mm^3 (1330mm^3) and requires a small clearance area of 10 x 35 mm^2 (350mm^2) above the top edge of the device ground plane of the smart phone.

1. PROPOSED DESIGN:

Fig. 1 shows the geometry of the proposed Triple band inverted-F antenna with inductive and capacitive shorting strips and capacitive feeding strip for mobile phone devices. In this design the antenna is mounted along the longer side of the device ground plane of smart phone and can be recessed in clearance region of 10 x 35 mm^2. The dimensions of the device ground plane are selected to be 150 x 200mm^2. The ground plane dimensions are typical for the 9.7-in. tablet computer, which is popular in the market. The antenna has a bent metal portion and a rectangular patch, which respectively, control the lower and higher bands of the antenna. The bent metal plate is the main radiating portion of the lower two bands (860MHz-1250 MHz and 1550 MHz-2800 MHz), while the rectangular patch is the main radiating portion of the high-band antenna. The bent metal plate is also connected through a chip inductor of 9.1nH (L1) to feeding strip. The inductor L1 effectively decreases the required length of the longer arm for the antenna operating in the low band, where in quarter-wavelength of the lowest frequency 860MHz is about 87.2 mm.

In this study, the longer arm is formed by connecting a bent metal plate of 3 x 5 x 35 mm^2 to two short stubs of triangle shape for minimum reflection at edges (section AB and CD) printed on a 0.8 mm thick FR4 substrate of size 30 x 35 mm^2 , relative permittivity 4.4, and loss tangent 0.024. Other parts of the antenna are including the shorter arm, the feeding strip, and two shorting strips are all printed on the same thin FR4 substrate. Dimensions of the antenna's printed metal pattern are same as on Fig. 1(b). The thickness of the antenna is 3mm only, which is promising for modern slim smart phone applications. The longer along the inner edge of section ABCD has a length of 43 mm only and its wide width can help improve the impedance matching over the low frequency regions.

By short-circuiting the antenna to the device ground plane through an inductive shorting strip (section ES) and a capacitive shorting strip (section GS1), dual resonance excitation for the antenna's lower and higher bands to achieve much widened bandwidths can be obtained. In the inductive shorting strip, a chip inductor of 9.3 nH (L2) is loaded therein. By further loading a chip capacitor of 3.0 pF (Cf) in the feeding strip (section FeE), an internal high-pass matching circuit is formed by the inductive shorting strip and capacitive feeding strip.

The high-pass matching circuit results in large bandwidth enhancements of the antenna's lower, mid frequency bands and has very small effects on the high-band operation.

On the other hand, the capacitive shorting strip short-circuits the antenna to the device ground plane through a coupling gap of length 10.3 and width 1.1 mm (g). The presence of the capacitive shorting strip greatly enhances the bandwidth of the antenna's higher band and has small effects on the low, mid band operation, functioning like a low pass matching circuit.

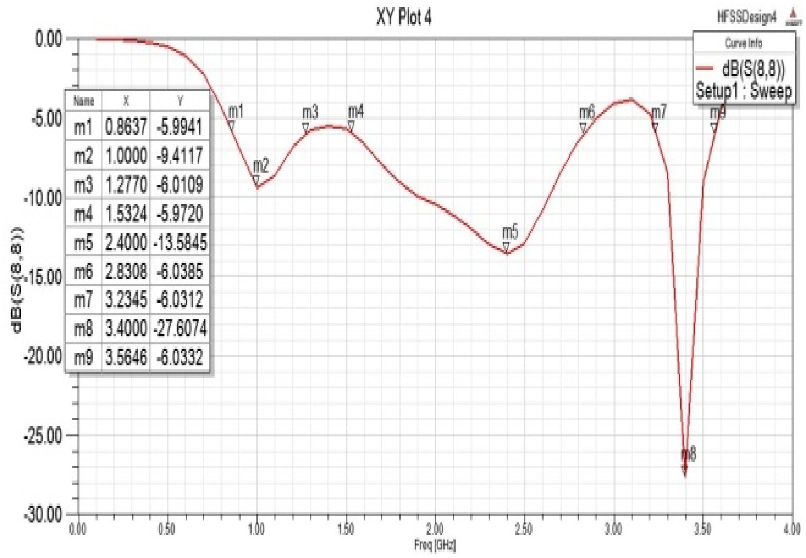


Figure 3: Simulated return loss for the proposed antenna

Fig. 3 shows the simulated return loss of the proposed design with three frequency regions of 860 MHz-1250 MHz with center frequency of 1GHz with return loss of -9.4dB, 1550 MHz-2800 MHz with center frequency of 2.4GHz with return loss value of -13.5dB and 3250 Mhz-3550 MHz with center frequency of 3..4Ghz with return loss of -27.6 dB .

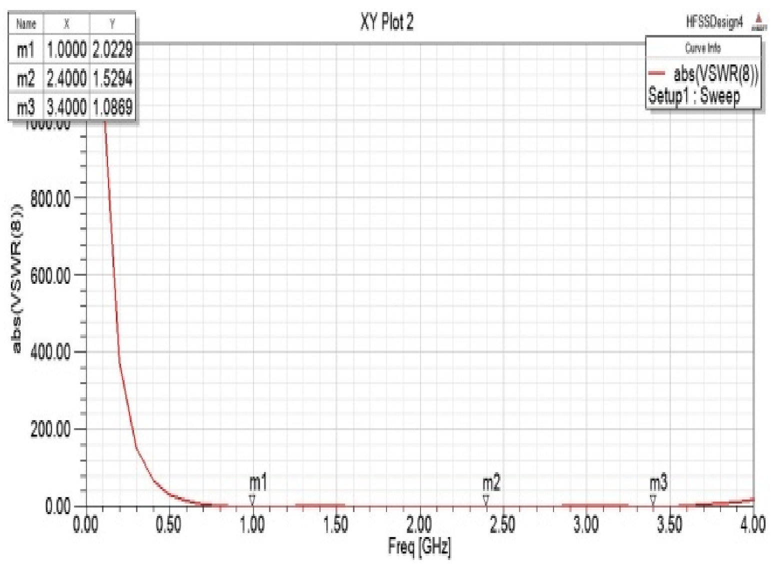


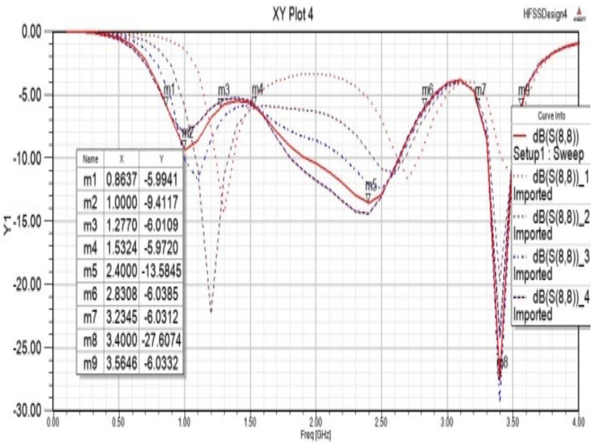
Figure 4: Simulated VSWR of the proposed antenna

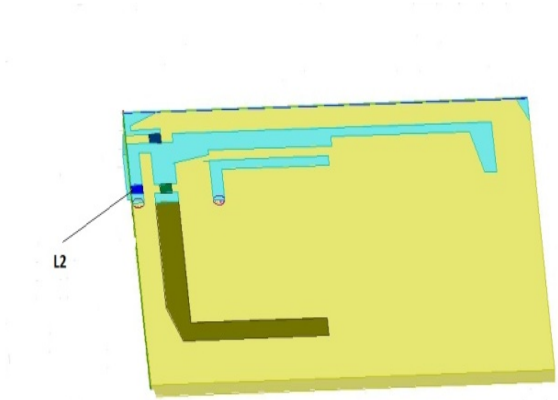
The VSWR values at mid frequency regions are shown in Fig. 4 with 1GHz is 2.02, 2.4GH is 1.52 and 3.4 GHz is 1.08 which ranges between 1-3 which are desirable for mobile phone application.

2. PARAMETRIC STUDIES

A. Effects of the Inductor L2

Results of the simulated return loss for the inductor L2 of 0, 3.1, 6.2, 9.3and 12.4nH are shown in Figure 5. The case with L2= 0 indicates (dB(S (8, 8,) _1) that a simple shorting strip is used, and there is no loaded chip inductor. In this case, large effects on the antenna's lower band are observed. This is mainly because the inductive shorting strip and capacitive feeding strip can function like an internal high-pass matching circuit. By adjusting the inductor L2 (9.3 nH selected in this study) the desired low band frequency and mid band frequency is obtained.



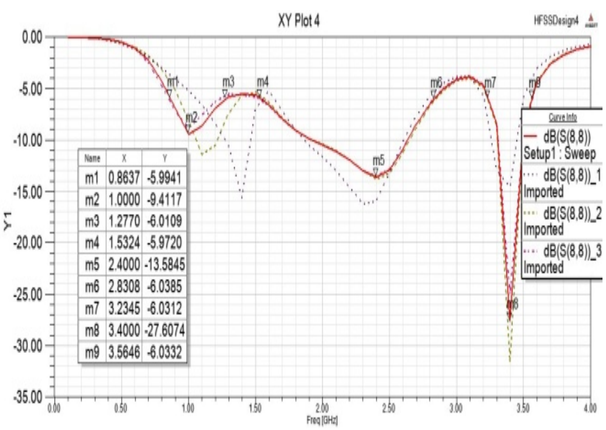


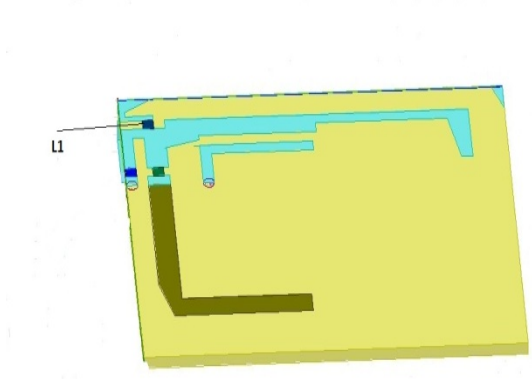
(dB(S(8,8,)_1) = 0 nH, (dB(S(8,8,)_2) = 3.1 nH, (dB(S(8,8,)_3) = 6.2 nH, (dB(S(8,8,)_4) = 12.4 nH and dB(S(8,8)) = 9.3 nH

Figure 5 simulated return loss as a function of shorting inductor L2 in the inductive shorting strip. Other parameters are the same as shown in Fig. 2

B. Effects of the Inductor L1

Results of the simulated return loss for the inductor L1 of 0, 4.5, 9.1and 12 nH are shown in Figure 6. The case with L1=0 indicates that longer arm is directly connected to the feeding strip. In this case, good coverage of the desired lower band cannot be obtained. When L1 increases, it is seen that longer arm is shifted to lower frequencies. By selecting L1 to be 9.1nH in this study, desired frequency bands are obtained.



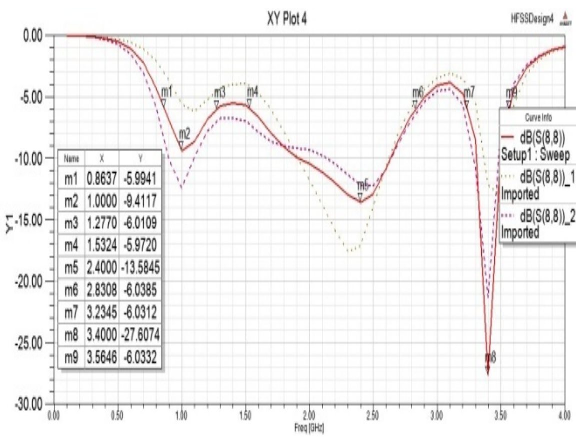


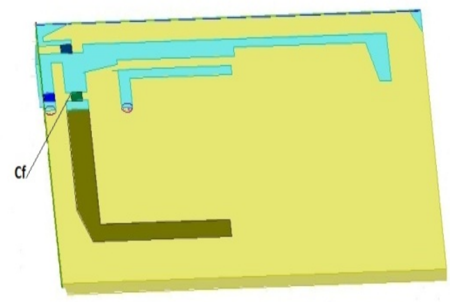
(dB(S(8,8,)_1) = 0 nH, (dB(S(8,8,)_2) = 4.5 nH, (dB(S(8,8,)_3) = 12 nH and dB(S(8,8)) = 9.3 nH

Figure 6 simulated return loss as a function of inductor L1 between the longer arm and feeding strip. Other parameters are the same as shown in Figure 2

C. Effects of the Capacitor Cf

Figure 7 shows the simulated return loss for capacitor Cf of 2, 3, and 4 pF. It is seen that when a larger capacitor is selected such as (Cf = 3 and 4 pF), small effects on the high-band operation are seen. This is mainly because the contributed capacitance decreases with increasing frequencies and, hence, the effects of capacitor Cf with larger capacitance will have smaller effects in the antenna's higher band. By selecting Cf to be 3pF the desired frequency bands are obtained.





(dB(S(8,8,)_1) = 2pF, (dB(S(8,8,)_2) = 4 pF and dB(S(8,8)) = 3pF

Figure 7 simulated return loss as a function of the capacitor Cf in the feeding strip. Other parameters are the same as shown in Figure 2.

3. RESULTS AND DISCUSSION

Figure 3 shows the simulated return loss of the designed antenna with dimensions shown in Figure1 with parametric values shown in Figure 2. The device ground plane of 150 x 200 mm^2 as shown in Figure 1, the device ground plane was cut from a 0.2 mm thick copper plate. The results of the simulated VSWR are shown in Figure 4. Results of the simulated radiation patterns are shown in Figure 8. The results are acceptable for practical mobile communication applications.

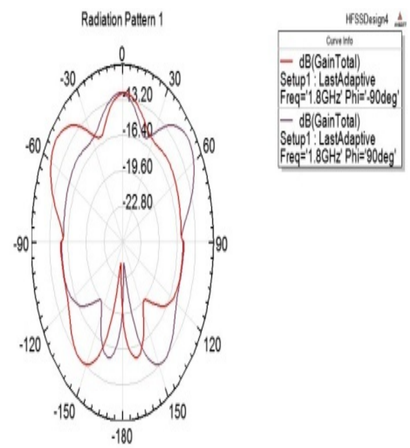


Figure 8: simulated radiation pattern for 1800MHz

4. CONCLUSION:

A Triple Band Inverted-F Antenna with an inductive shorting strip and capacitive shorting strip for providing two wide operating bands to cover the 860 MHz-1250 MHz and 1550 MHz-2800 MHz, One narrow operating band of 3250 MHz-3550 MHz has been proposed. The wide lower and mid bands are controlled by the bent metal plate, the inductive shorting strip and the capacitive feeding strip. The narrow higher band is mainly controlled by the antenna's rectangular radiating patch and the capacitive feeding strip (the high band antenna). In addition, the antenna's bent metal plate is coupled with feeding strip through a chip inductor, thereby greatly decreasing the resonant length for generating a resonant mode in the lower band. Hence, with two wide operating bands obtained, the antenna requires a small ground clearance of 10x35mm^2 inside a smart phone. The antenna has a thin thickness of 3 mm. The results indicate that the proposed antenna is promising for smart phone applications in all three frequency regions.

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