Wideband 4G Mobile Device Planar Antenna Using Couple Feeding Technique

By

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ABSTRACT:

This paper deals with the design and fabrication of a wideband planar antenna capable of operating at both the wireless wide area network (WWAN) and long term evolution (LTE) with frequency bands LTE2.6GHz/2.3GHz/WLAN2.4GHz and WWAN (DCS1800/PCS1900/UMTS2100) respectively, using the couple feeding techniques. The proposed antenna has two sides with one side containing a rectangular radiator loaded with two rectangular strip shorted to ground plane through a narrow meandered strip line. While the other side contains a rectangular coupling strip that is fed with 50 Ω microstrip feed-line. Result comparison between, the measured from the fabricated prototype and the simulation shows that the antenna has a nearly omnidirectional radiation pattern. The -6 dB operation bandwidth of the measured and simulated antenna are 1.81 GHz to 2.97 GHz and 1.46 GHz to 2.81 GHz respectively. This shows that the designed antenna can operate in the mobile device environment.

Keywords: Wireless communication, LTE, Couple feeding, meandered strip line.

INTRODUCTION

Widespread deployment in wireless communication leads to technological advancement. Mobile wireless devices focuses on multiple connectivity through smaller and lighter mobile devices with improved processors, faster access and more memory (Ban, Chen, Li, & Wu, 2013; Caimi, 2011). Limitation in size and weight in current mobile devices are what makes planar antennas the current state of the art for mobile wireless communication. Monopole planar antenna received a considerable attention from researchers owing to their simple size, light weight and low profile in addition to their main feature of resonating at quarter wavelength. This makes it suitable for use as internal antenna and key component of studies to generate and cover up the GSM/LTE/WWAN frequency bands (Ban, Chen, et al., 2013; Sathish, 2015). Various researches on printed microstrip-fed antennas, such as folded loop, planar inverted-F antenna (PIFA), monopole slot, and thin ceramic substrate has been described (Ban, Chen, et al., 2013; Ban, Liu, Li, Guo, & Kang, 2013; Chen & Wang, 2012; Chi & Wong, 2008; Rajagopal, Chennakesavan, Subburaj, Srinivasan, & Varadhan, 2017; Sim & Chien, 2013; Wong, Lin, & Tseng, 2006). The designs has been reported to approximately reduce the size of the antenna to about 40 × 5 mm^2 (Ban, Chen, et al., 2013; Chi & Wong, 2008). Due to the bending nature of the monopole based planar antenna, there will be an increase in the antenna thickness within the range of 4 mm to 10 mm which results in a narrow band characteristic. Furthermore, the antenna geometry is sophisticated making them difficult to optimize and fabricate there by increasing the cost of fabrication (Z.-W. Hu, Wei, Mo, & Chang, 2016; Sim & Chien, 2013).

LTE is attractive towards achieving high data rates and abundant multimedia services (Ban, Chen, et al., 2013). The main target towards LTE developments are the various modes of operation, system flexibility and interoperability with current radio technologies. To minimize the effect of multipath, LTE makes use of orthogonal frequency-division multiple access (OFDMA) for downlink and single carrier frequency division multiple access (SC-FDMA) in the uplink (Copet, Marchetto, Sisto, & Costa, 2017; Jamal, Horia, Maria, & Alexandru, 2011). Several mobile planar antenna for LTE/WWAN operation has been design and presented, among a few are coupled-fed PIFA form by lengthening and folding the antenna (Jiu-Sheng, Qing-Hua, & Jian-Zhong, 2016; Kang & Wong, 2010). This approach offers narrow bandwidth in the upper and lower band and also increases the thickness and size of the antenna to about 120 × 60 × 5.6 mm^3. To improve the resonant mode without using metal strip, a coupled fed loop antenna with a dimension of 55 × 10 × 4 mm^3 was proposed (Sim & Chien, 2013). This approach involve introducing a matching circuit but at the cost of increasing the length of the antenna. The use of thin ceramic substrate to reduce the antenna thickness to about 0.5 mm compared to the FR4 has been proposed in (C.-L. Hu, Huang, Kuo, Yang, & Liao, 2010). This resulted in an increase in the cost of fabrication as the substrate use is very expensive.

In this paper, a wideband 4G planar antenna was proposed based on the coupling feeding technique to be used in a mobile wireless device. The impedance matching of the proposed antenna was improved by the inclusion of two rectangular strips, narrow meandered line and tuning stub on the radiator which are coupled fed through a long rectangular feed-line. To cover the LTE/WWAN frequency bands, three resonant modes at 2.03 GHz, 2.4 GHz, and 2.66 GHz are induced. Validation of the proposed antenna was carried out through comparison of simulation results with measured results from the fabricated prototype.

The remainder of the paper is organized as follows. Section 2 gives a description of the methodology used in designing the antenna which is followed by the simulation results and discussion in section 3. Finally, the conclusion is presented in section 4.

METHODOLOGY

In this section of the paper, the methodology used in the design of the antenna is presented. The antenna is segmented into two parts that is front-side and the back-side as shown in Figure 1. The front-side of the proposed antenna contains a centrally placed rectangular feed-line of about 105 ×2.9 mm^2 fed through a probe of 50 Ω. The reason for placing the rectangular feed-line at the center is to improve the impedance matching at low frequency bands. On the back-view, a rectangular radiator of about 25 × 35 mm^2 is placed which is linked to the ground plane via a narrow meandered strip line of about 0.4 mm wide as shown in Figure 1c. The radiator section of the antenna is loaded with two rectangular strips (slit1 and slit2) as shown in Figure 1c each with dimension presented in Table 1. This is to improve the impedance matching at the LTE/WLAN bands. The resonant modes are induced at $Fr1$ = 2.03 GHz, $Fr2$ = 2.4 GHz, and $Fr3$ = 2.66 GHz and to achieve good resonance at the three resonant modes, a small narrow tuning stub of about 8 × 0.9 mm^2 is extended to the left bottom of the radiator (see Figure 1c).

Table 1. Dimension of the proposed antenna

Parameter	W	W_f	W_{s2}	W_{ts}	L	$L1$	L_{s1}	L_{ts}	L_{s2}	g
Value(mm)	35	2.9	1	0.9	105	8.6	15	8	15.7	1.5

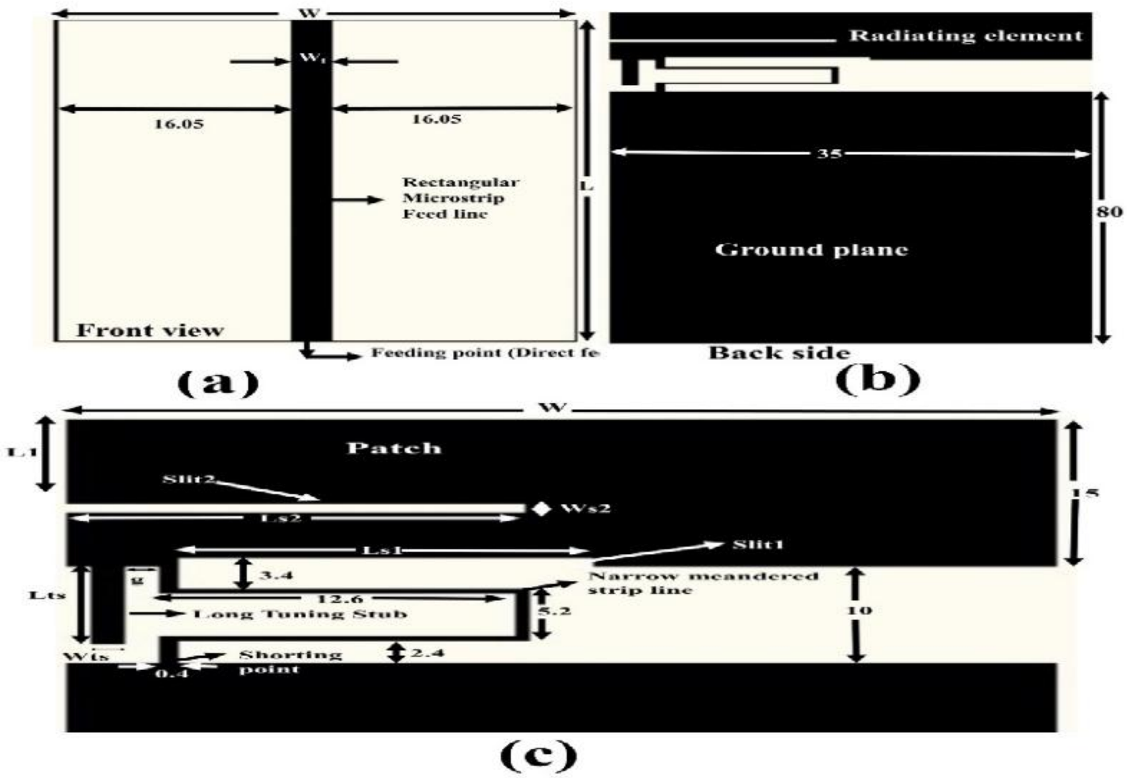
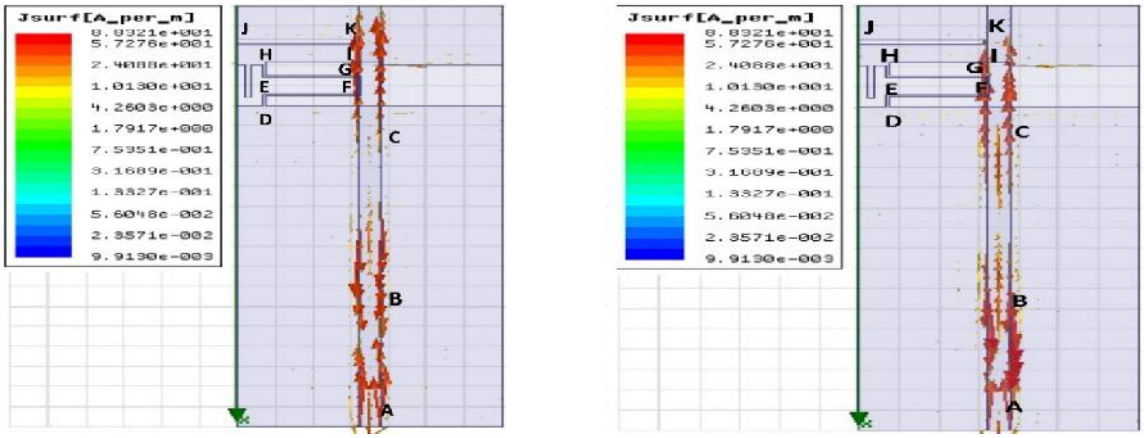
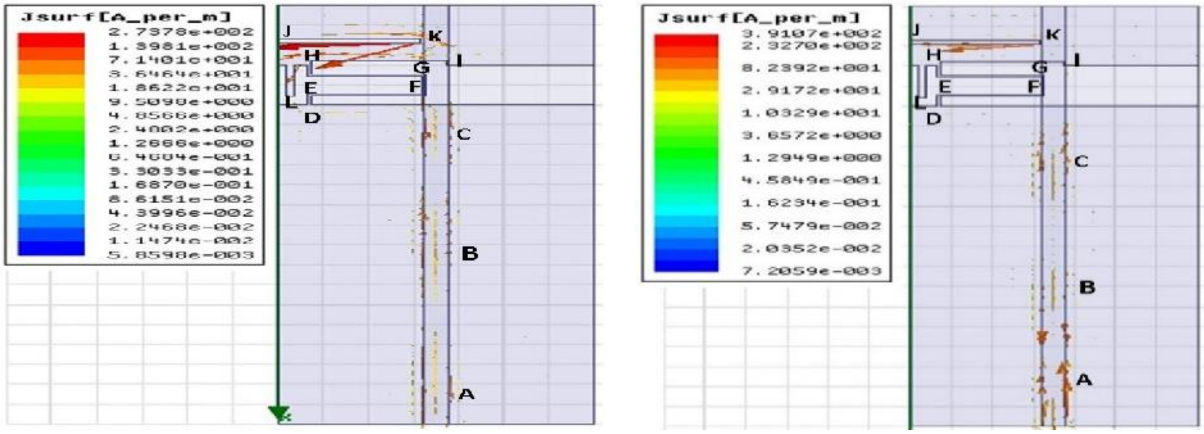


Figure1. Geometry of the proposed Antenna (a) Front view (b) Back View and (c) Radiator section.

To Identify the sources of unwanted electromagnetic waves and minimizes interferences due to high clock frequency wave, the surface current distribution of the proposed antenna is determined and presented in Figure 2. Figure 2 (a, b) illustrate the current excitation from feed-line A-B-C, which subsequently concentrated at the narrow meandered line D-E-F-G-H between ground plane and the radiator. The two rectangular slits H-I-K-J which are cut at about quarter wavelength helps in resonating *Fr1* at 2.03 GHz. In Figure 2 (c and d) more current circulates on slit2 which contributes in achieving *Fr2* at 2.4 GHz and *Fr3* at 2.66 GHz at one-third of the wavelength.



(a) (b)



(c) (d)

Figure 2. Surface current distribution for the proposed dual band antenna at (a) 2.03GHz (front view), (b) 2.03GHz (back view), (c) 2.4GHz, and (d) 2.66GHz.

RESULT AND DISCUSSION

The high frequency structural simulated (HFSS) is used to determine the initial characteristic and performances of the proposed antenna at -6 dB return loss for practical mobile phones usage. The three resonant modes are achieved by considering the following elements of the antenna which are the narrow meandered line, the two rectangular slots, tuning stub and the rectangular feed-line. Figure 3 shows the simulated reflection coefficient magnitude of the antenna for different narrow strip positions. Using a rectangular radiator of about 15 × 35 mm^2 shorted to the ground plane by a long narrow strip placed at the center (labelled (a) in Figure 3), the antenna can be seen to have a center frequency of 1.82 GHz with an operation band within 1.17 GHz to 2.4 GHz which is not within the proposed operating frequency band. Shifting the long narrow strip to the left hand side as shown in (b), the antenna can be seen to excite at 1.95 GHz with an operating band within 1.15 GHz to 2.45 GHz. In (c), meandering the narrow strip to about 35.5 mm provides two resonant modes at 2.11 GHz and 2.64 GHz which are close to the proposed resonant mode *Fr1* and *Fr2* respectively. The operation bandwidth of the antenna is 1.6 GHz to 2.8 GHz which is *Fr1* at about 58 % and *FR2* at about 46 %. It was observed that meandering the narrow strips line provides the number of distinct resonance modes, at the cost of narrow impedance bandwidth.

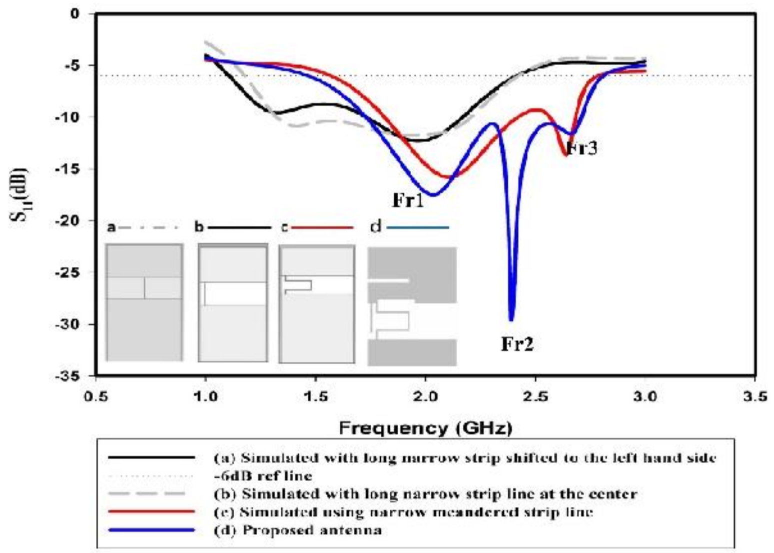
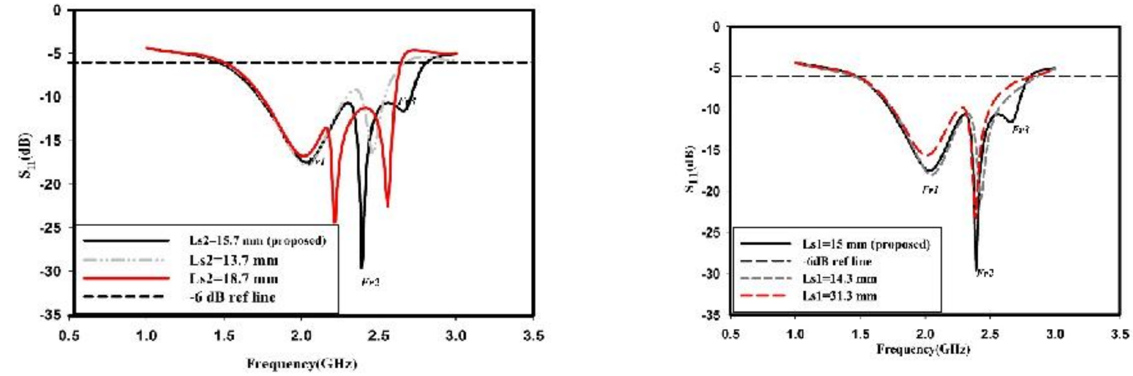
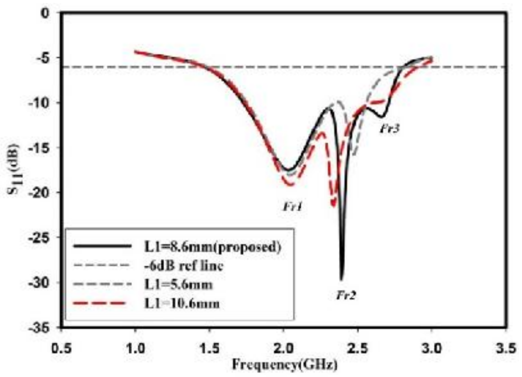


Figure 3. Reflection coefficient magnitude versus frequency for different narrow strip line

The impedance matching in the upper two resonance modes (*Fr2* and *Fr3*) depends on the length and position of two rectangular slits. Figure 4 (a), (b) and (c) respectively show the reflection coefficient magnitude comparison for different length of slit2 (*Ls2*), length of slit1 (*Ls1*), and the position of slit2 (*L1*). From Figure 4a, it can be seen that for slit2 length above the quarter wavelength, there are distortions in the upper modes. This subsequently narrow the bandwidth to about 2.21 GHz and 2.56 GHz respectively. With *Ls2* of about 15.7 mm which is below the quarter wavelength and *L1* at about 8.6 mm, a good impedance matching is obtained that covers 2.4 GHz to 2.7 GHz band. The bandwidth can be improved by proper alignment of slit1. From Figure 4b, the bandwidth can be seen to increase from 820 MHz to about 982 MHz by making *Ls1* at about 15 mm.



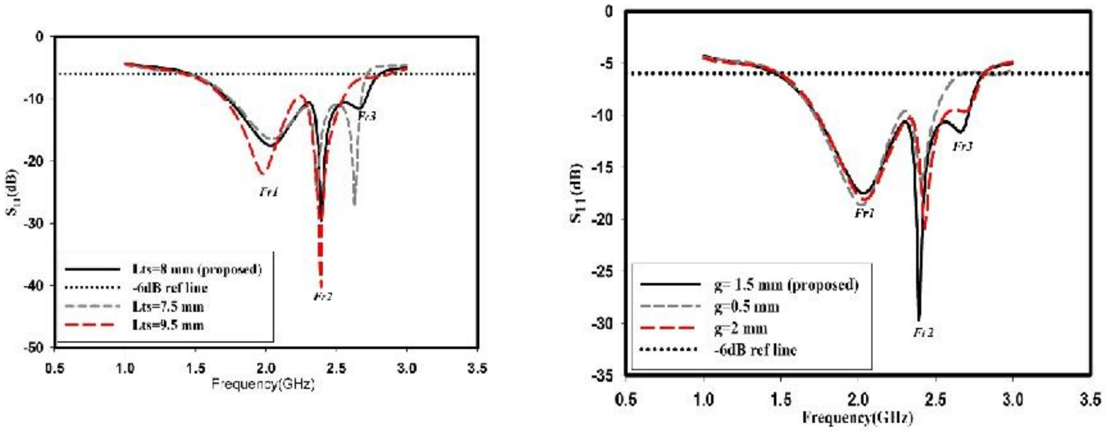
(a) (b)



(c)

Figure 4. Reflection coefficient magnitude against frequency for different values of (a) *Ls2* (b) *Ls1*. (c) *L1*

To achieve good resonance modes at the band of interests (*Fr1*, *Fr2*, and *Fr3*), the long narrow tuning stub as shown in Figure 1c was introduced. Figure 5 show the reflection coefficient magnitude comparison against frequency for different tuning stub length (*Lts*) and gap (*g*). From Figure 5a, it can be seen that increasing the *Lts* to about 9.5 mm increases the rejection at *Fr1* and *Fr3* mode. The rejection was reduced in the *Fr2* and *Fr3* mode with *g*=1.5 mm as shown in Figure 5b. This was due to coupling strength adjacent to the ground plane which affect both the impedance matching and the desired bandwidth. A tuning stub dimension of 8 × 0.9 mm^2 resulted in optimum resonance mode at the band of interest as shown in Figure 5.



(a) (b)

Figure 5. Reflection coefficient magnitude against frequency for different values of (a) *Lts*, (b) *g*.

The position of the rectangular feed-line also contributes to improving the impedance matching. Figure 6 shows reflection coefficient magnitude comparison for different position of the rectangular feed-line on the antenna. It can be seen that placing the rectangular feed-line at either the left or right of the antenna results in absolute mismatch. Placing the rectangular feed-line at the center resulted in good impedance matching which can be seen in Figure 6.

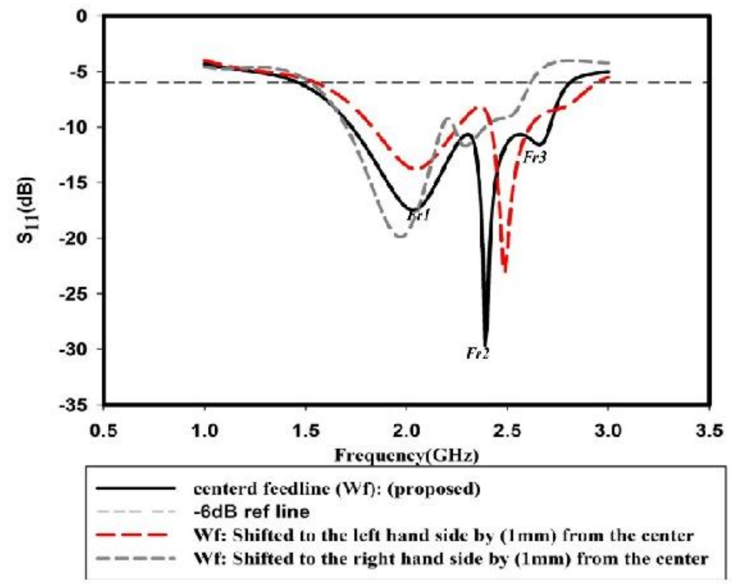


Figure 6. Reflection coefficient magnitude against frequency for different rectangular coupling strip positions.

Figure 7 shows the reflection coefficients magnitude comparison between the simulated and the measured from the fabricated couple-fed antenna as shown in Figure 8. As stated earlier, the three resonant mode considered at *Fr1*=2.03 GHz, *Fr2*=2.4 GHz, and *Fr3*=2.66 GHz. Result comparison shows that the simulated bandwidth of the proposed antenna at -6 dB reflection coefficient is from 1.46 GHz to 2.81 GHz with 2.6 GHz at about 56 % of the bandwidth. The measured operation band of the antenna is from 1.81 GHz to 2.97 GHz with 2.6 GHz at about 45 % of the bandwidth. This means that the fabricated antenna can be used within the WWAN band (PCS180/DCS1900/UMTS2100/LTE2300) and LTE/WLAN (2.30 GHz to 2.80 GHz). The slight variation between the simulated and measured result was caused by unexpected tolerance encountered during the fabrication process. The measured far field radiation pattern of the proposed antenna at the three resonance mode in the E-plane and H-plane exhibit a nearly normalized omnidirectional pattern which can be seen in Figure 9. The realized gain in all bands of interest ranges from 1.31 dBi to 6.31 dBi which corresponds to an inclined efficiency from 45 % to 89 %.

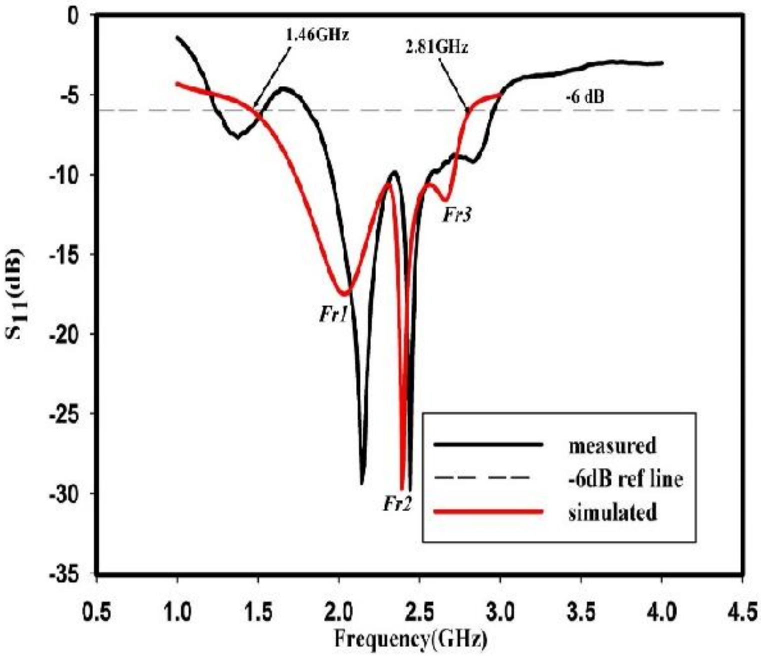


Figure 7. Comparison between the measured and simulated reflection coefficient magnitude against frequency for the proposed antenna.

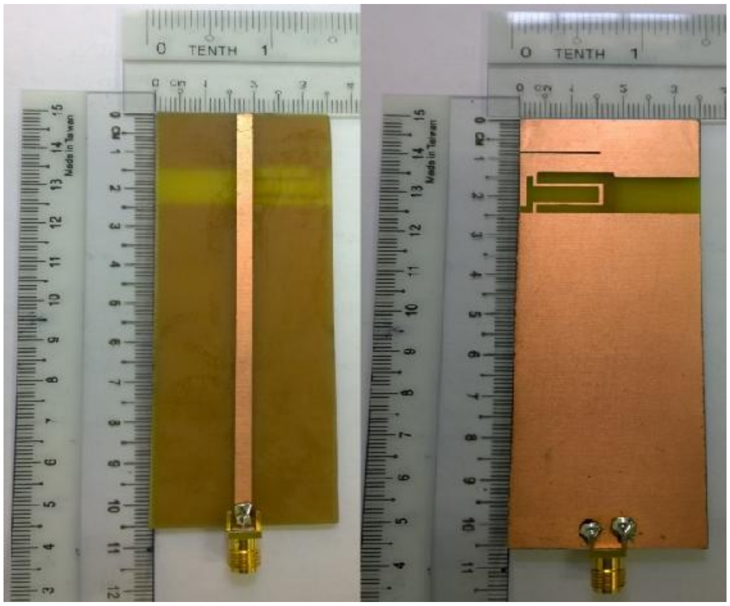
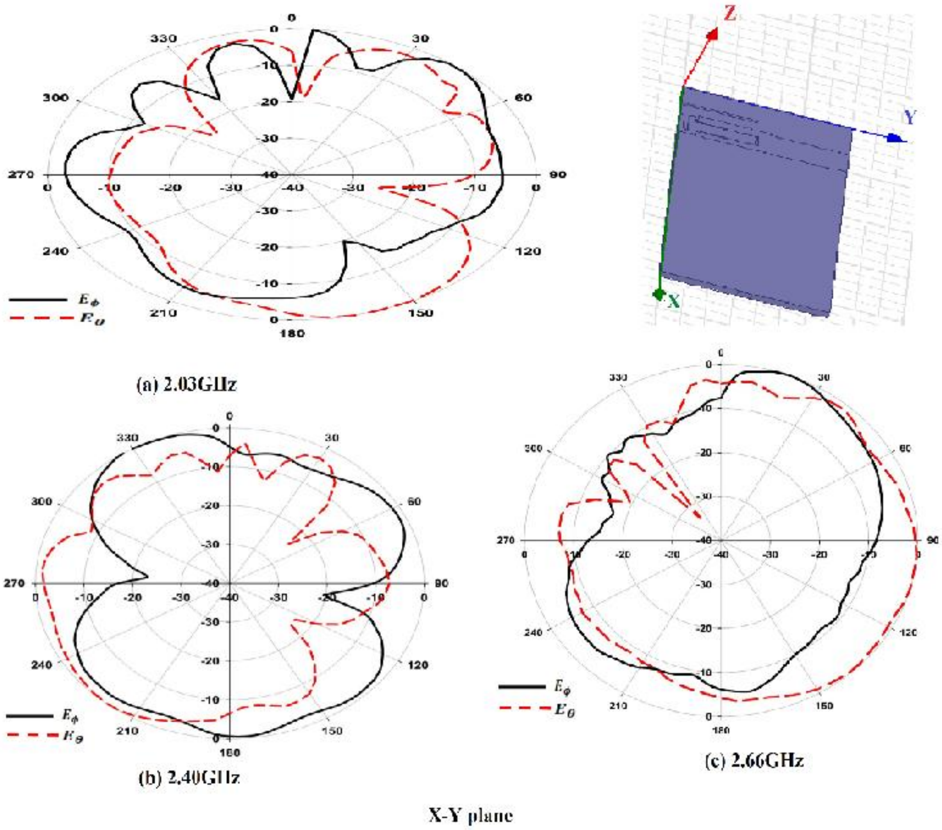


Figure 8. Fabricated prototype of the proposed antenna.



(a) 2.03GHz

(b) 2.40GHz

(c) 2.66GHz

X-Y plane

Figure 9. Measured 2-D radiation patterns (a) 2030MHZ (b) 2400MHz and (c) 2660MHz

CONCLUSION

In this paper, a wideband planar antenna based on the couple feeding technique was proposed. The proposed antenna is capable of operating at both the WWAN and LTE frequency bands. To improve the impedance matching, two rectangular strips (slit1 and slit2), narrow meandered line and tuning stub are introduced on to the radiator which are couple-fed through a long rectangular feed-line. Three resonant mode are induced in the antenna band of operation at 2030 MHz, 2400 MHz and 2660 MHz. The dimension of the proposed antenna is 105 × 35 × 1.6 mm3 which makes it suitable for use in a thin profile mobile device and also a potential candidate of operations at LTE/WWAN frequency band.

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