Low-Profile Antenna for Ten Band WWAN/LTE/WiMAX Smartphone Applications

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ABSTRACT
A small antenna which works in ten bands for slim and wide screen internal smartphone application is proposed here. It consists of a feeding strip, a coupling strip and shorting strip, which can be easily printed on the FR4 substrate. In this scheme three chip inductors and a chip capacitor are loaded on the strips. A parallel resonant circuit is introduced in the design in order to enhance the bandwidth of lower bands. This antenna has a size of 5x40mm and a height of 2mm which is promising for slim and wide screen smartphones. The proposed antenna can operate in GSM850/DCS/ PCS/UMTS2100 /LTE2300/2500/2690, WiMAX-3100/3500, Amateur radio and Bluetooth frequency bands. The design considerations and the antenna parameters are explained in detail.

General Terms
Antenna, WWAN/LTE/WiMAX smartphones.

Keywords
Low-profile, Parallel resonant circuit, Ten band antenna.

1. INTRODUCTION
Smartphones are one of the main communication tools now a days. People prefer smartphones that are slimmer and have wider screen. In order to meet this, antennas with wide operating bands and compact size are always necessary for making such phones.

As the height of the antenna increases, so does, the thickness of the smartphone. Mobile antennas are placed mainly at top or bottom edge of the smartphones. So if the width of the antenna is reduced, length of the touch screen can be increased [1]. This makes the phone more attractive and desirable in the consumer point of view. Based on these above said facts, many multiband antennas are proposed and studied. The antenna reported in [1] has a height of 3mm and covers 7 frequency bands which covers GSM850/950/DCS/PCS/ UMTS2100/LTE2300/2500 [9], [3]. But the number of frequency bands are less and the height of the antenna is more. In [2] an antenna with octa band is introduced. That covers most of the required bands. It also contains a parallel resonant circuit for achieving bandwidth in lower frequency bands. But it is not suitable for slim smartphones as the height of the antenna is 10mm.

Most of the proposed designs with small sizes [5], [7] cannot cover the whole ten-band WWAN/LTE/WiMAX (four WWAN bands of GSM850/1800/1900/UMTS2100, three LTE bands of LTE2300/2500/2690, Amateur radio-1300 and two bands of WiMAX 3100/ 3500).

The antenna presented here is mainly formed by three portions: a feeding strip, shorting strip and a coupling strip. The shorting strip with an inductor on it provides a wide lower band for GSM850, 1300MHz operation, and the feeding strip provides a wide upper band for DCS/PCS/ UMTS/LTE and WiMAX operation [10]. Details of the proposed antenna's design and parameters studied are presented and discussed in the following sections.

2. ANTENNA CONFIGURATION
Figure 1(a) shows the geometry of proposed antenna for internal smartphone applications. Its detailed structure and dimensions are shown in Figure 1(b). A 0.8mm thick FR4 substrate of relative permittivity 4.4 and loss tangent 0.024 is used as the system circuit board. The proposed antenna is placed on the top left of the system circuit board with a size of 5x40mm. On the back side of the FR4 substrate, a ground plane with the length of 115 mm and the width of 60mm is introduced to serve as the system ground of the smartphone. Also, it has an extended ground of 5x20 mm connected to the system ground. A 50Ω mini coaxial feed line is used as the feed.

The antenna in Figure 1(b) consists of a feeding strip (BC), a shorting strip (DH) and a coupling strip (EF). The coupling strip is connected to the shorting strip (DH) and it provides a good coupling between the feeding strip and the shorting strip. The shorting strip is loaded with a chip inductor of 5.9nH which can provide two resonant modes that can cover the lower band at 850MHz and upper band at 2100MHz. The lower bandwidth can be enhanced with the help of a parallel resonant circuit [2], [8] connected to the feeding strip. It consists of a 3.3nH chip inductor and 4.3pF chip capacitor. The higher order resonant mode of shorting strip and the fundamental mode of feeding strip forms the higher frequency bands. This covers DCS/PCS/UMTS2100/LTE2300/2500/ 2690 and WiMAX operating frequency bands.

Figure 1(c) shows the shorting points of the antenna with the ground. The shorting strip is shorted via hole to the ground at the point Y with a patch. The feeding strip is connected to the parallel resonant circuit, a chip inductor of 1.2nH, the patches and the coaxial feed. This is shorted to the ground at the point X with a wire port loaded with 25Ω resistance. This load helps to achieve a good return loss below -3dB for the lower bands, ie at 850MHz and 1300MHz.

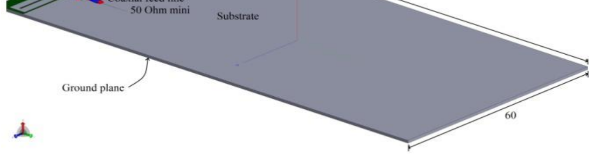


Figure 1(a): Geometry of the low-profile antenna for ten-band operations in the internal smartphone applications

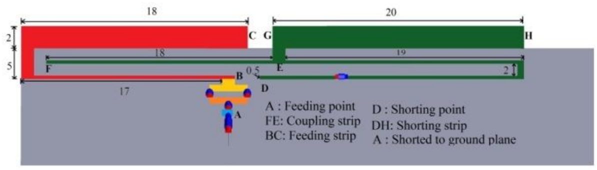


Figure 1(b): Detailed dimension and structure of the proposed antenna. (Unit mm)

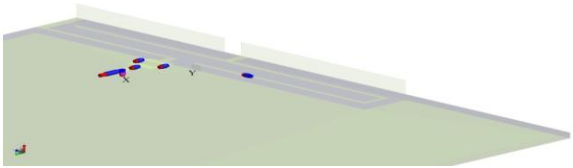


Figure 1(c): Shorting point on the ground

3. PARAMETERIC ANALYSIS

The different parameters in the proposed antenna are discussed in this section.

3.1 Parallel resonant circuit

The parallel resonant circuit is formed by a 3.3nH chip inductor and a 4.3pF chip capacitor. The parameters in the band-stop matching circuit including L and C can be decided by formula (1).

$$f_c = \frac{1}{2\pi\sqrt{LC}} \tag{1}$$

Then,

$$LC = \frac{1}{(2\pi f_c)^2} \tag{2}$$

f_c is cutoff frequency, which is chosen as 1.3GHz in this paper.

$$LC = \frac{1}{(2\pi f_c)^2} = 15\times10^{-21} \tag{3}$$

The values of the inductor and capacitor should satisfy the above formula (3). Furthermore we should choose suitable values of the inductor and capacitor combining the impedance matching of the antenna. As an example,

$$L_1C_1 = 3.3\times10^{-9}\times4.3\times10^{-12} = 14.19\times10^{-21}$$
$$L_2C_2 = 3.6\times10^{-9}\times3.9\times10^{-12} = 14.04\times10^{-21}$$
$$L_1C_1 \approx L_2C_2 \approx LC$$

3.2 Coupling feed length

The length of the coupling feed can create changes in the result as it enlarge the coupling between shorting strip and feeding strip. The proposed length of the coupling feed is 18mm as it gives required results.

Great effects on the impedance matching of the frequencies over the lower band are seen when the length is varied from 8mm to 18mm. The bandwidth and the return loss can be analyzed from the different tables shown. From Table 1 the coupling feed length is taken as 18mm. Frequency bands from 800MHz to 3450MHz is analyzed. It includes all the ten frequencies for the smartphone applications. Also it have a greater bandwidth and return loss below -3dB which is sufficient for an antenna to radiate. The frequency range from 1750 to 1950MHz includes two required frequencies, ie DCS and PCS frequency bands. Similarly the other frequency ranges shown in the Table 1 includes multiple frequencies required for the smartphone applications. Furthermore the antenna can attain a good impedance matching at this length.

From Table 2 it is clear that when the length of the coupling strip is 13mm, amateur radio, Bluetooth and LTE frequencies are not obtained. Since no dips are shown in this frequency range as in Figure 2, the antenna is not capable of radiating at those frequencies. In the present world, which is after the increased speed of data transfer would not be satisfied with this design, as it does not radiate at LTE bands.

Now in the next length, Table 3 shows how the antenna radiated when the length of the coupling strip is 8mm. Three frequency ranges ie, 1200 to 1350MHz and 2300 to 2800MHz are not radiating. So as the case discussed necessary bands are not in this design.

Table 1: Analysis when coupling feed length = 18mm

Length of Coupling feed(mm)	Frequency range (MHz)	Bandwidth (MHz)	Return Loss(dB)
18	800-900	17	-4
	1200-1350	10	-3
	1750-1950	150	-6
	2050-2200	130	-10
	2300-2500	200	-11
	2600-2800	200	-8
	3100-3450	300	-12

Table 2: Analysis when coupling feed length = 13mm

Length of Coupling feed(mm)	Frequency range (MHz)	Bandwidth (MHz)	Return Loss(dB)
13	800-900	22	-15
	1200-1350	-	-
	1750-1950	150	-6
	2050-2200	130	-10
	2300-2500	-	-
	2600-2800	200	-5
	3100-3450	150	-12

Table 3: Analysis when coupling feed length = 8mm

Length of Coupling feed(mm)	Frequency range (MHz)	Bandwidth	Return Loss
8	800-900	5	-4
	1200-1350	_	_
	1750-1950	150	-6
	2050-2200	150	-10
	2300-2500	_	_
	2600-2800	_	_
	3100-3450	200	-12

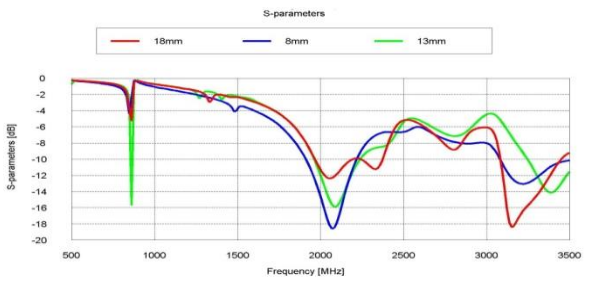


Figure 2: S parameter of the proposed antenna at different coupling lengths.

3.3 Microstrip patches

Different patches are placed in between feeding strip and the coaxial feed. This will helps in connecting the different chip inductors and chip capacitors. The value of the chip inductor placed between parallel resonant circuit and the coaxial cable is 1.2nH. The dimension of the smaller patch is 1x1mm and the bigger patch is 1x3mm.

The design of the antenna is much similar to the antenna proposed in [1]. But instead of using lumped port, wire port is used in this design. It will act as a short between the ground plane and the feeding strip. Also, in order to attain the lower frequency bands a load of 25Ω is added in the design. The antenna designed in [6] has only a height of 3mm and this is similar to [1]. Most of the necessary upper and lower bands are also attained. But as the width is 13.5mm it will greatly reduce the touch screen space. Figure 2 shows the comparison of S parameter based on the different coupling lengths.

When the S parameter of antenna with the coupling length of 13mm is analyzed the lower frequency band shows a good return loss of -15 dB but the bandwidth is very less. Also it is not capable of generating the dip at upper band LTE frequencies. For 8mm the return loss at 2100MHz is -18.5dB which is much good when compared with the other graphs obtained by 18mm and 13mm long coupling strip. But the antenna is not radiating at Bluetooth and LTE frequency bands. It is not capable of creating dip at lower frequency bands too. Also return loss of -3dB is enough for an antenna to radiate.

4. RESULTS AND DISCUSSIONS

The proposed low-profile antenna for ten band WWAN/ LTE/WiMAX for smart phone applications is designed and simulated using FEKO ver 5.5. The S parameter and the 2-D pattern of the antenna gain are also plotted. S parameter of the antenna is shown in Figure 3. The total gain obtained is good enough at the frequencies which the antenna radiates. The gain obtained is shown in Figure 4 and the 2-D pattern of the gain at individual frequencies 850MHz, 1800MHz, 2100MHz and 2300MHz at different planes are shown in Figure 5.

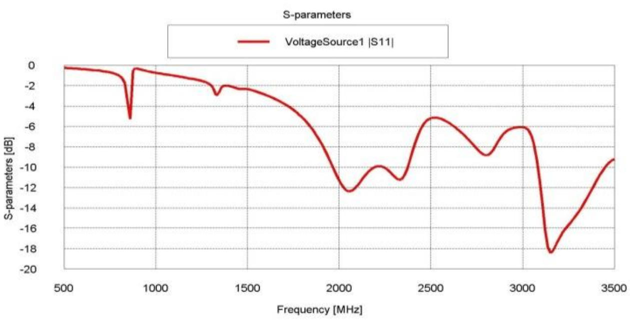


Figure 3: S parameter of the proposed antenna

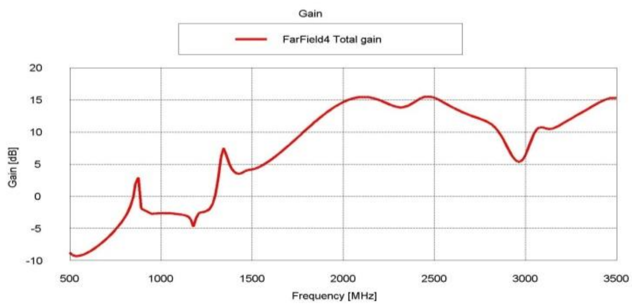
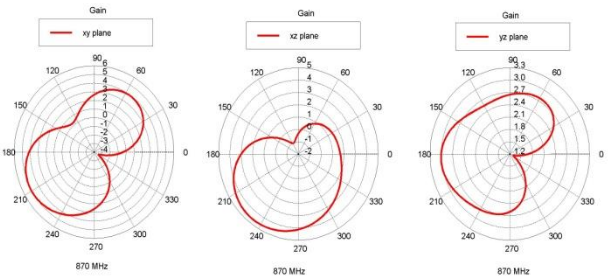
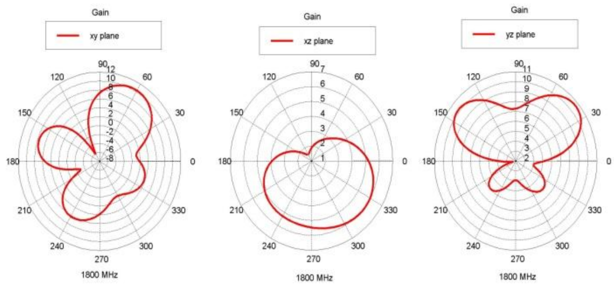


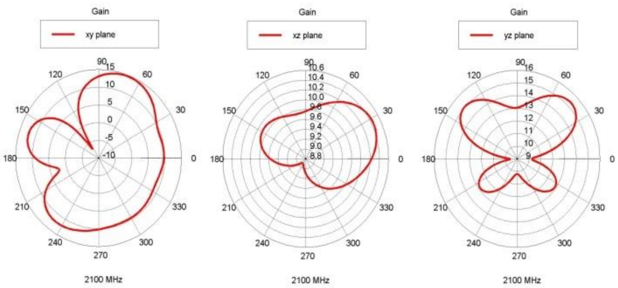
Figure 4: Gain of the proposed antenna



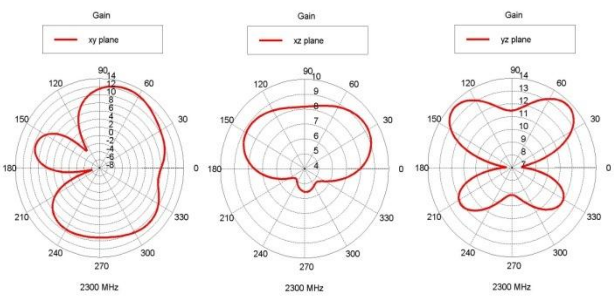
(a)



(b)



(c)



(d)

Figure 5: Measured 2-D gain patterns at (a) 870 MHZ (b) 1800MHz (c) 2100 MHz (d) 2300MHz for the proposed antenna

5. CONCLUSION AND FUTURE SCOPE

A low-profile antenna for ten band WWAN/LTE/WiMAX operations in the internal smartphone application is proposed and studied. By introducing a parallel resonant circuit, a coupling strip, a feeding strip and a shorting strip, bandwidth is enhanced and the antenna could radiate at multiple frequency bands. The proposed antenna can operate at the frequency bands of 800-900, 1710 to 2960 and WiMAX. The obtained measured results including return loss and antenna peak gain are presented, which can meet the requirements for mobile systems.

The main highlights of this paper are, the small antenna height of 2mm and a width of 5x20mm both of which promise smartphones that are slimmer and has wider touch screen space, comparing to the current mainstream phones.

Future scope lies in the use of the proposed antenna for manufacturing slimmer smartphones with wider touchscreen and to analyse its SAR value.

6. REFERENCES

[1] Yong-Ling Ban, Yun-Fei Qiang, Zhi Chen, Kai Kang, and Joshua Le-Wei Li, "Low profile narrow frame antenna for seven-band WWAN/LTE smartphone applications" IEEE Antennas and Wireless Propagation letters, vol. 13, 2014.

[2] Y.-L. Ban, J.-H. Chen, S. Yang, J. L.-W. Li, and Y.-J.Wu, "Low-profile printed octa-band LTE/WWAN mobile phone antenna a using embedded parallel resonant structure," IEEE Trans. Antennas Propag., vol. 61, no. 7, pp. 3889–3894, Jul. 2013.

[3] F. H. Chu and K. L. Wong, "Planar printed strip monopole with a closely-coupled parasitic shorted strip for eight-band LTE/GSM/UMTS," IEEE Trans. Antennas Propag., vol. 58, no. 10, pp. 3426–3431, Oct. 2010.

[4] M. Zheng, H. Y. Wang, and Y. Hao, "Internal hexa-band folded monopole/dipole/loop antenna with four resonances for mobile device," IEEE Trans. Antennas Propag., vol. 60, no. 6, pp. 2880–2885, Jun. 2012

[5] Y. Li, Z. J. Zhang, J. F. Zheng, Z. H. Feng, and M. F. Iskander, "A compact hepta-band loop-inverted F reconfigurable antenna for mobile phone," IEEE Trans. Antennas Propag., vol. 60, no. 1, pp. 389–392, Jan. 2012.

[6] K. L. Wong, M.-F. Tu, C.-Y. Wu, and W.-Y. Li, "On-board 7-band WWAN/LTE antenna with small size and compact integration with nearby ground plane in the mobile phone,"Microw. Opt. Technol. Lett., vol. 52, no. 12, pp. 2847–2853, Dec. 2010.

[7] C. M. Peng, I. F. Chen, and C. T. Chien, "A novel hexa-band antenna for mobile handsets application," IEEE Trans. Antennas Propag., vol. 59, no. 9, pp. 3427–3432, Sep. 2011.

[8] K. L. Wong, Y.C.Liu, and L. C. Chou, "Bandwidth enhancement of WWAN/LTE tablet computer antenna using embedded parallel resonant circuit," Microw. Opt. Technol. Lett., vol. 54, no. 2, pp. 305–309, 2012.

[9] Yun-Fei Qiang and Yong-Ling Ban, "A Hepta-band WWAN/LTE Antenna Design for Metal-rimmed Smartphone Applications," PIERS Proceedings, Guangzhou, China, August 25-28, 2014.

[10] Yong-Ling Ban, Cheng-Li Liu, Joshua Le-Wei Li, Fellow, IEEE, and Rui Li, "Small-Size Wideband Monopole With Distributed Inductive Strip for Seven-Band WWAN/LTE Mobile Phone," IEEE Antennas and Wireless Propagation, letters, vol. 12, 2013.