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Research paper

Multiple Band Mobile Antenna for LTE, GSM, PCS, UMTS & IoT Applications

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Abstract

A compact planar inverted folded antenna for LTE, GSM, PCS and UMTS applications is presented in this work. This paper provides the comprehensive study on the placement of mender line ground and its effect on the performance characteristics of the antenna operating bands. Results of intensive investigations by computer simulations are provided for antenna parameters like reflection coefficient (<-10 dB), VSWR (2:1), bandwidth, radiation patterns, field distributions and showcased the technical write-up in this paper. The proposed antenna offers an average gain of 3.4 dB and directivity of 3.8 dB at operating bands of 860 MHz, 960 MHz, 1800 MHz, 2100 MHz and 2700 MHz, which includes 4G and covers most of the applications bands for mobile communication. An impedance bandwidth of 32% at first resonant band (GSM), 26.6% at second resonant band (PCS), 26% at third resonant band (LTE) and 21% at fourth resonant frequency (UMTS) are obtained.

Keywords: *Global System for Mobile (GSM), Long Term Evolution (LTE), Monopole, Planar Inverted Folded Antenna (PIFA), Universal Mobile Telecommunication Systems (UMTS), Wideband.*

1. Introduction

The rapid growth in wireless communication industry requires the handheld devices, which can adopt new kind of form factors such as the smart phones with a large display, ultra-slim profile and also should be capable of operating with new technologies in mobile communications. The smart phones has been substituted many of the earlier form factors such as bar-type, sliders etc. [1]. Moreover, the applications of smart phones are increased day by day such that their real purpose is extended from telephony to multimedia applications like cameras, mobile TV and bulk data transmissions with a high data rates. In parallel, the technological evolution has been carried out through several generations which include GSM, EDGE, UMTS, and LTE etc. Moreover, the other data sharing applications has been carried out through the Bluetooth, WLAN, WiMAX, etc. This scenario creates the scarcity in space to fit the antenna, so the developments of low profile multiband antennas with wide operating bands are required.

Monopole radiating elements have been proved as an attractive candidate for mobile applications, as they can provide the stable radiation performance, in low profile configurations, and at low costs [2-4]. The PIFA has good physical features, which employs simple structure with small size and also it is a good member for multiband applications. In [5] researchers presented a design, which consists of a hook-shaped slot in the radiating patch and a pair of square-rings and rotated I-shaped slots etched in the ground plane to obtain the multiple operating bands. The PIFA element generally determines the number of frequency bands, whereas the bandwidth at low frequencies can be determined by the dimensions of ground plane without incorporating the slots [6-7]. In [8], the ground plane of PIFA is incorporated with slots for tuning the PCB and to obtain broadband but a drawback is identified in [9-10] that the possibility of interference, while placing the electronic components. In [11], a compact multiband (GSM/DCS/PCS/UMTS) PIFA is presented with a coupling feed and achieved the good impedance matching at 900 and 1900 MHz with a great decrease in large input impedance value. A planar PIFA antenna with coupled-feed is discussed in [12], such that it is operated in its $\lambda/8^{th}$ resonant mode instead of using the conventional $\lambda/4$ mode and achieved a wide operating band that supports GSM850/900. Also, this antenna is excited with two $\lambda/4$ modes to obtain penta-band performance. Planar meander-line antennas with three branch strips in quarter wavelength structures are designed to operate at GSM, DCS/PCS and WLAN bands [13]. The monopole antennas loaded with two-dimensional meander line discussed in [14], provides multiple bands in the UWB range. In [15], another multi-banding approach for planar antenna with a coupling between U-shaped monopole and the S-shaped strip also utilized a meander line coupling with a monopole in clip-shape. In [16], two printed radiating elements are combined with L-loaded printed-IFA to obtain multiband, and realized with some slow-wave structures.

This article provides a novel structure of PIFA antenna for multiple communication band applications. The structure of the antenna is suitable for laptop or tablet devices for real time placement in the device cabin. The geometry and the design aspects are thoroughly discussed in the subsequent section.

2. Antenna Geometry

The proposed antenna structure with PIFA configuration is presented in this section.

When width of the feeding post is almost zero then $L = \lambda/4$ --- (1)

In general, the resonant length of the PIFA can be taken as L – W = λ/4 = C/f√ε$_r$ -------- (2), the resonant frequency can be calculated once we know the dielectric constant of the material.

Basic equation for resonant frequency, velocity of light and wavelength is C = λf ------ (3), the resonant frequency f = $C_0/\lambda\sqrt{\varepsilon_r}$ --- (4).

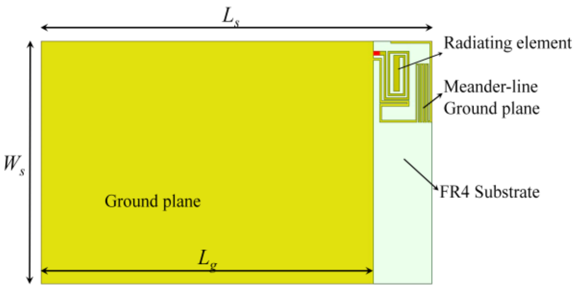


Figure 1:. Antenna Architecture

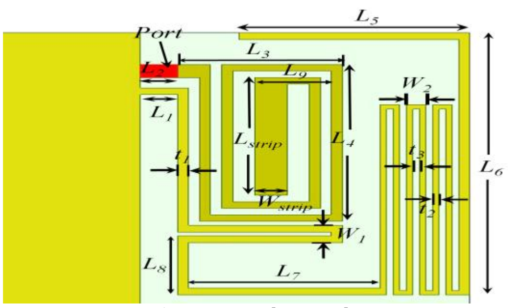


Figure 2.: Radiating Element Structure

Table 1:. Geometrical Parameters of Antenna

Parameter	L_s	W_s	L_g	L_1	L_2	L_3	L_4	L_5	L_6	L_7
Value in mm	100	60	85	1.7	1.7	7.5	12	10.5	20	8.7
Parameter	L_8	L_9	L_{strip}	W_{strip}	W_1	W_2	t_1	t_2	t_3	h
Value in mm	4.5	3.5	9	1.5	1.3	0.9	0.5	0.3	0.3	0.8

Fig 1 shows the proposed antenna architecture and Fig 2 shows the radiating element structure. Antenna was constructed on FR4 substrate with dielectric constant 4.4 and loss tangent 0.02. The dimensions of the proposed antenna are presented in Table 1. The overall dimension of the antenna is 100X60X1.6 mm. Finite element method based HFSS tool is used to model the antenna and simulation results are collected from the same tool.

3. Results and Discussion

The bandwidth of a PIFA depends on a few parameters, specifically the size ratio of the planar element, the height of the short-circuit plate, and the ratio of width of the patch to length of the patch. Fig 3 shows the reflection coefficient of the antenna with respect to the operating frequencies. It is been observed that the antenna is resonating at quad band with impedance bandwidth of 10% at fundamental resonant frequency, 15% at second resonant frequency, 35% at third resonant frequency and 25% at fourth resonant frequency. A bandwidth of 700 MHz is obtained at third resonant frequency, which covers PCS and LTE application bands. At fundamental resonant frequency GSM band and at fourth resonant frequency UMTS band is covered by the antenna with good impedance bandwidth.

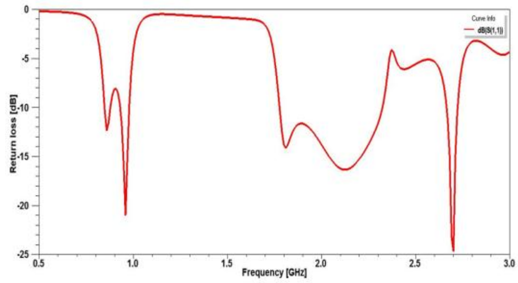


Figure 3:. Return loss plot of proposed antenna

Table 2.: Operating bands of the antenna from reflection coefficient plot

Resonant frequencies	Return loss [dB]
860 MHz	-12.3755
960 MHz	-21.0156
1810 MHz	-14.1580
2120 MHz	-16.3460
2700 MHz	-24.6890

Operating bands	848.5 MHz – 879.5 MHz	931.6 MHz – 979.5 MHz	1777.2 MHz – 2323.3 MHz	2663.5 MHz – 2722.4 MHz

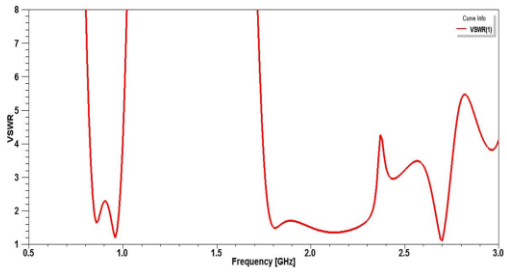


Figure 4.: VSWR characteristics

The operating bands and their bandwidth are clearly mentioned in the table 2. The voltage standing wave ratio is one of the important parameter to analyze the bandwidth of the antenna. Ideally it should be one and practically 2:1 ratio should be maintained. Fig 4 shows the VSWR of 2:1 ratio at operating bands and table 3 gives the VSWR operating bands and corresponding bandwidth.

Table 3. Operating bands of the antenna from VSWR plot

Resonant frequencies	VSWR
860 MHz	1.6335
960 MHz	1.1953
1810 MHz	1.4873
2120 MHz	1.3593
2700 MHz	1.1238

Operating bands	847.7 MHz – 882.9 MHz	929.0 MHz – 980.3 MHz	1775.6 MHz – 2328.1 MHz	2661.6 MHz – 2723.5 MHz

Input impedance characteristics of the antenna for real, magnitude and imaginary formats are presented in Fig 5. An ideal impedance of 50 ohms can be observed at resonant bands from the obtained result.

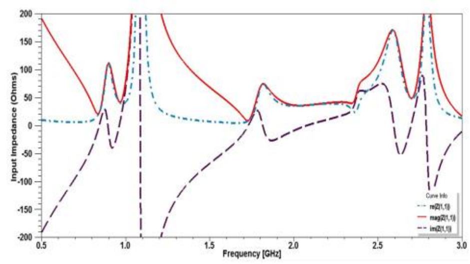


Figure 5:. Input Impedance characteristics

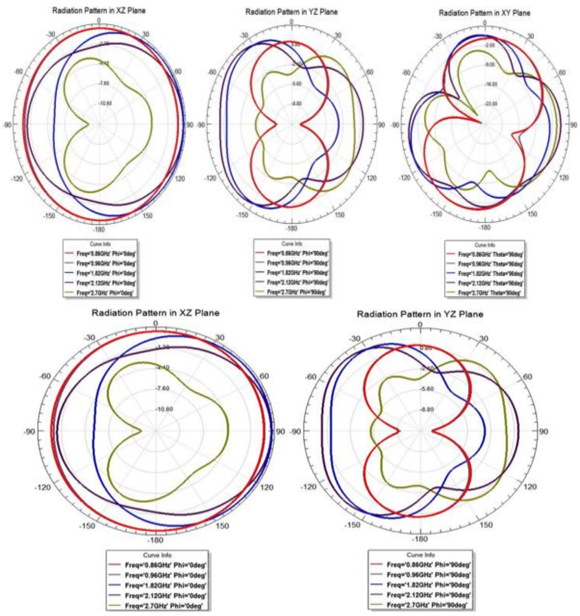
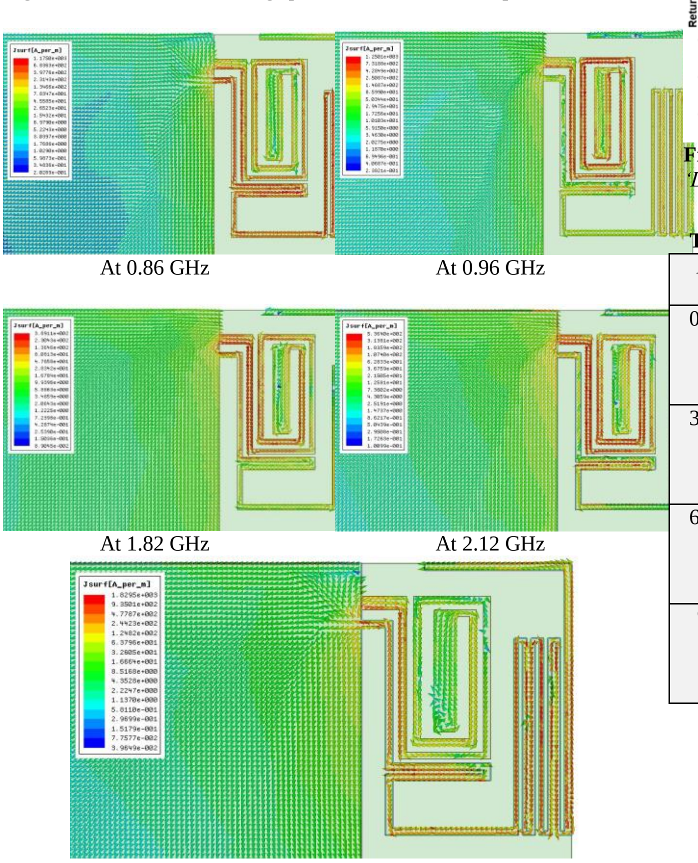

(a) phi = 0 degrees (b) phi = 90 degrees

Figure 6:. 2D Radiation Patterns at different operating frequencies

The far field radiation patterns of the antenna at different resonant frequencies are given in Fig 6. At lower operating band antenna is showing omni directional pattern in H-field and at higher operating band antenna is showing quasi omni directional pattern.


At 0.86 GHz At 0.96 GHz

At 1.82 GHz At 2.12 GHz

At 2.7 GHz

Figure 7:. Surface Current Distributions at operating bands

The surface current distributions of the antenna at resonant frequencies are presented in Fig 7. At 860 MHz the current distribution over the radiating element is more when compared with 960 MHz and 1820 MHz. At higher operating band of UMTS antenna current distribution over the surface shows more intensity. The gain of the antenna with respect to frequency is presented in Fig 8. A peak realized gain of 3.2 dB is obtained in the operating band between 1.7 to 2.3 GHz. At fundamental resonant frequency and at other bands, an average gain of 1.5 dB is attained.

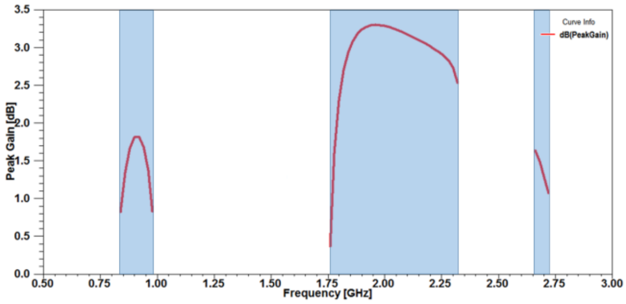


Figure 8:. Peak Gain Vs Frequency characteristics

The parametric analysis of the proposed antenna is performed with the electromagnetic tool to optimize the dimensions. Length of the strip and width of the strip are considered for parametric analysis and the corresponding simulation results are presented in Fig 9 and 10. The changes in the operating frequencies with respect to the length of the strip are presented in Table 4.

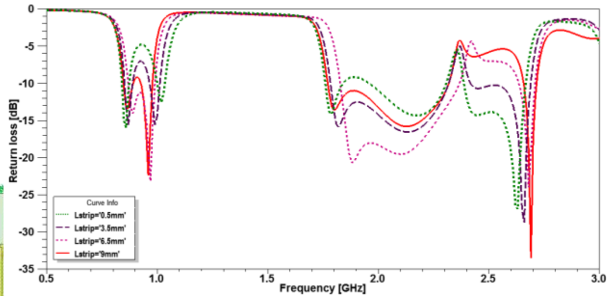


Figure 9:. Parametric investigation on varying the length of the strip *'Lstrip'*

Table 4:. Parametric analysis tabulation with change in length of the strip

Lstrip	Lstrip				
	Band 1	Band 2	Band 3	Band 4	Band 5
0.5 mm	841.2 MHz – 874.1 MHz	1000 MHz – 1035.2 MHz	1760.0 MHz – 1840.0 MHz	1960.0 MHz – 2307.1 MHz	2386.6 MHz – 2667.1 MHz
3.5 mm	852.7 MHz – 889.2 MHz	1012.8 MHz – 1783.5 MHz	2318.2 MHz – 2416.4 MHz	-	-
6.5 mm	869.2 MHz – 990.4 MHz	1827.8 MHz - 2367 MHz	2634.8 MHz – 2709.3 MHz	-	-
9 mm	847.9 MHz – 892.5 MHz	925.6 MHz – 979.1 MHz –	1771 MHz - 2319.3 MHz	2656. 6 MHz – 2716 MHz	-

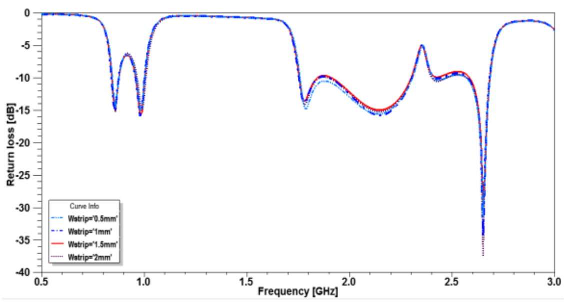


Figure 10:. Parametric investigation on varying the length of the strip *'Wstrip'*

4. Conclusion

A compact mobile antenna was designed to operate in LTE, GSM, PCS and UMTS bands with good impedance bandwidth. The following conclusions are drawn from the proposed antenna. Antenna is operating in 860 MHz, 960 MHz, 1800 MHz, 2100 MHz and 2700 MHz which includes 4G and covers most of the applications bands for mobile communication. An impedance bandwidth of 32% at first resonant band (GSM), 26.6% at second resonant band (PCS), 26% at third resonant band (LTE) and 21% at fourth resonant frequency (UMTS) is obtained. The corresponding bandwidths are 31 MHz, 47.9 MHz, 546.1 MHz and 59 MHz respectively. Length of the strip at feed point and width of the strip at feed point are considered for parametric analysis and the corresponding simulation results shows that the effect of strip length is more compared with the width of the strip with respect to resonant frequency. The proposed model is showing omni directional radiation in H-plane and quasi omni in E-plane at resonant frequencies and a peak realized gain of 3.2 dB is obtained in the operating band between 1.7 to 2.3 GHz. At fundamental resonant frequency and at other bands an average gain of 1.5 dB is attained.

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