International Journal of Applied Engineering Research ISSN 0973-4562 Volume 10, Number 24 (2015) pp 43960-43965

Study and modelling of triple-band Planar Inverted-F Antenna

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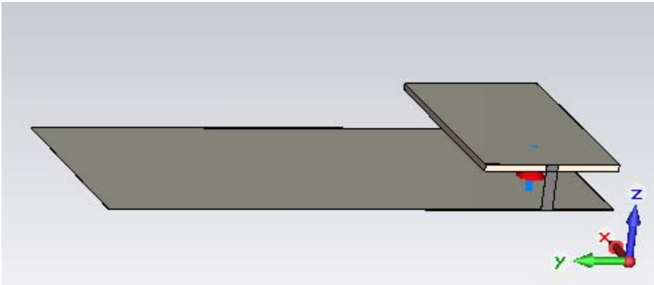
Abstract
This paper, presents novel designs for a triple-band planar inverted-F antenna operating at 0.9 GHz (GSM), 1.8 GHz (DCS), and 2.45 GHz (Bluetooth/Wifi). We have designed a triple band PIFA antenna with simple structure. The key technology is that the slots are built on the traditional PIFA antenna radiation surface. The Multi-band antenna can be got through this method. After studying parametric antenna, we reached a total efficiency, which exceeds 80% in three bands and a gain values 2.03 dB, 3.23 dB and 5.32 dB respectively in the GSM, DCS and Bluetooth/Wifi bands. The parameters performance considered in this work is the resonant frequency, return loss, bandwidth, radiation pattern, gain and the electromagnetic field, and the current delivered by the proposed antenna. All results of the simulations were done by CST Microwave Studio simulation software.

Keywords: Triple-band PIFA, The parameters performance, GSM, DCS, Bluetooth/Wifi, slots.

Introduction
Nowadays, the phone is not just traditional communications equipment for most people.With the popularity of smart phones, the rapid development of mobile Internet and mobile shopping and the universal of public Wifi hotspots, the mobile terminals with multifunctional features has been mentioned on the agenda. As an important component of mobile devices, mobile phone antenna plays a vital role in a wireless communication system. C. W.Chiu et al [2] proposed a method for studied a Planar inverted-F antenna due to its low profile, small size, simple to manufacture, easy to conformal and low radiation for the human, has been favored by many manufacturers. S. K.Oh et al [1] proposed a method can make the antenna work in multi-mode state by producing different shape of the slots in the surface of the PIFA antenna radiating surface, which accommodate the various functions of the mobile phone. In a system of communication, antennas are components which require a particular study while trying to improve their performances and to adapt them to the most recent applications. In the face of the growth of the diverse standards such as the GSM, DCS, UMTS,… [1-3], the new antennas must be capable of covering the maximum of the frequency bands corresponding to its various services at a minimum of dimensions.
Antenna PIFA or quarter of wave is the most used in the systems of communication. She combines several techniques, worth knowing the use of slots, eliminates parasites[4], short-circuited and capacitor loads [5] to optimize their performances on one hand and generate bands dedicated to the new applications [6-7-10]. At present, many double-bands PIFA antennas have been designed [2].
But now, researches about the tri-band antennas are not as many as the double-band antennas. Some have designed the tri-band antenna with the skill of multiple feed points and multiple patches. But this method has many disadvantages, for example, taking more space and the structure is complex that is not beneficial for the small communication terminals[9]. This article is completed on the foundation of multi-bands antenna researches has announced. And we have designed a triple-band PIFA antenna with simple structure. It is in this general framework, that we get a PIFA antenna which works at frequencies of GSM 900, DCS 1800 and Bluetooth/Wifi 2450[7]. In the progress of design, in order to achieve a triple-band antenna we must to adjust the location of the slot [8].

Design PIFA antenna
As shown in Figure 1, the designed antenna has a rectangular radiating patch witch length is Lp = 40 mm and width Wp = 24 mm. The patch in placed at a height h=8 mm from the ground plan. The last has a length Lg=90mm and a width Wg=40. The patch is matched to the ground plan via a rectangular shorting plate. The shorting plate has a width Ws=2.5 mm and a length Ls=8 mm. The patch is integrated on a dielectric substrate such FR-4 having a relative constant dielectric ε_r equal to 4.3, a relative permeability μr equal to 1, a loss tangent tan δ equal to 0.0018 (cont.fit) and a thickness he equal to 1.2 mm. The PIFA antenna is fed by a coaxial cable of excitation having a characteristic impedance Zc equal to 50 **Ω** placed at D=5 mm.



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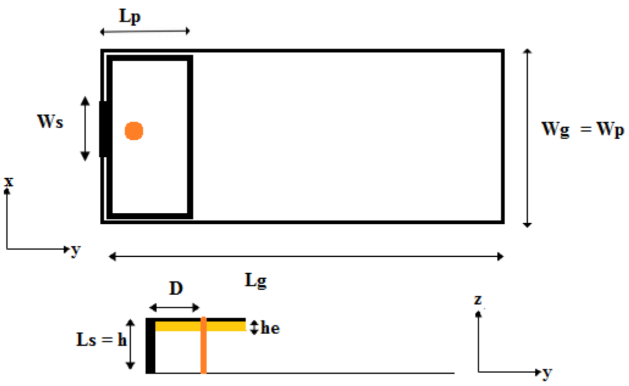


(b)

Fig.1. The designed antenna. (a) Perspective view ; (b) Top and Side view.

We proposed a PIFA has the resonance frequency 0.9 GHz.The geometric parameters of the patch antenna are determined from the following equations [1]:

$$F_r = \frac{C_0}{4\sqrt{\varepsilon_r}(L_p + W_p - W_s)} \qquad (1)$$

C_0 is the speed of light,
We define the center frequency of the GSM as F_1 equal to 900MHz, the center frequency of the DCS as F_2 equal to 1800MHz and the center frequency of the Bluetooth/Wifi as F_3 equal to 2450MHz. Figure 2 shown the surface structure of the antenna radiation, on which the surface is divided into three parts by the slots. The outermost part produces the low-frequency resonant frequency F_1,the middle part produces the resonance frequency F_2 and the innermost part of the resonance frequency F_3.
These results can be demonstrated from the calculated the loss power density in the three structures. The total density of the loss power (Eq.2) is defined as the sum of the densities of the loss power in dielectric, loss power in conductor and loss power of adaptation and its verified by Seif et al [11].

$$P_{loss} = \frac{1}{2}\sigma_d \int E^2 \partial v + \left[\frac{\pi\mu_0 f_R}{\sigma_c}\right]^{\frac{1}{2}} \int H^2 \partial s + \frac{(\rho - 1)}{100} P_s \qquad (2)$$

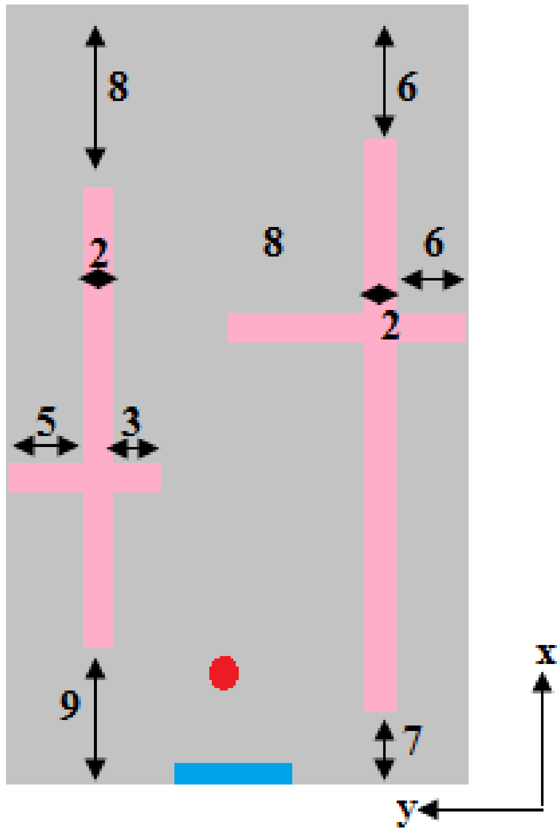
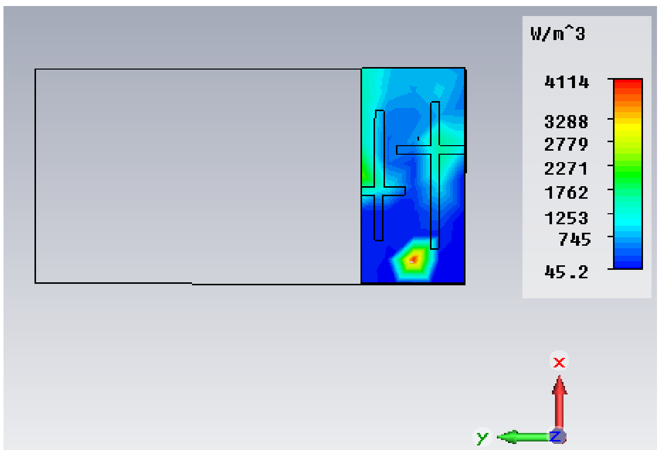


Fig.2. Geometric radiating patch (unit mm)

Whith σ_d and σ_e are respectively Dielectric conductivity and Conductor conductivity and Ps is Power supplied [watt]
The total power loss density for the triple-band PIFA antennas is shown in Figure below.



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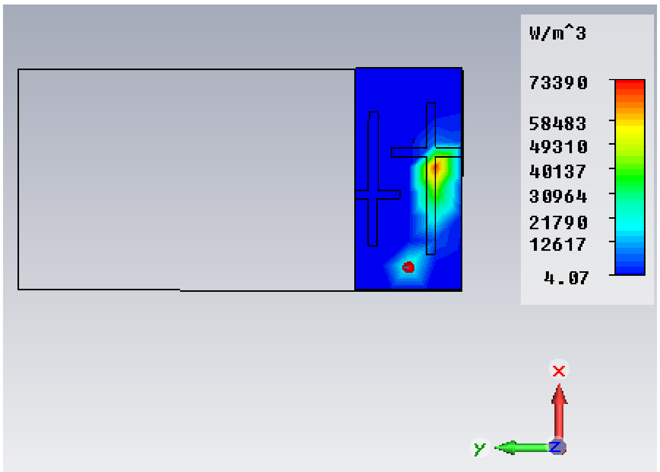

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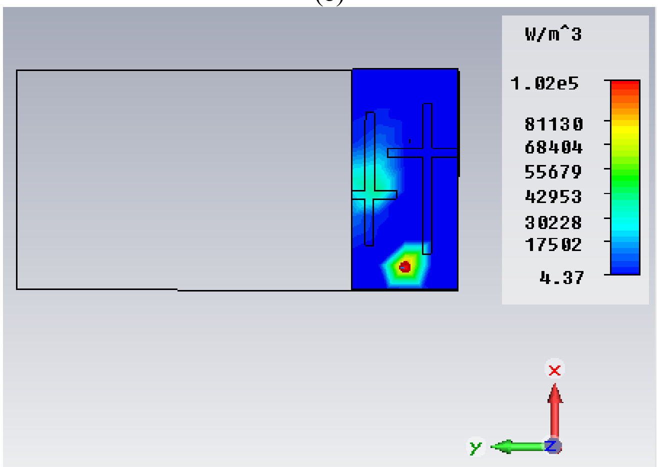


(c)

Fig.3. Power loss density for the triple-band PIFA antennas: (a) with 900MHz, (b) with 1800MHz, (c) with 2450MHz.

Therefore, to the results in Figure (3), we conclude the high value of the power loss density is obtained from the GSM band equal to 4114 W/m^3 by the patch, the high value of the power loss density is obtained for the DCS band equal to 73398 W/m^3 by the left dual-slots and the high value of the power loss density is obtained from the Bluetooth/Wifi band equal to 102000 W/m^3 by the other dual-slots.

Results and discussions

A. Return loss

From the results of simulations prepared by CST Microwave Studio software, we note that our PIFA antenna having three resonant frequency : F_1 equal to 0.9 GHz with a return loss S_{11} equal to-21 dB, F_2 equal to 1.8 GHz with a return loss S_{11} equal to-17.2 dB and F_3 equal to 2.45 GHz with a return loss S_{11} equal to-17 dB,as shown in Figure 4:

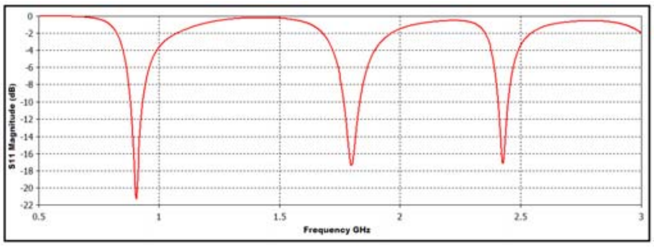


Fig.4. Simulated return losses of the tri-band antenna

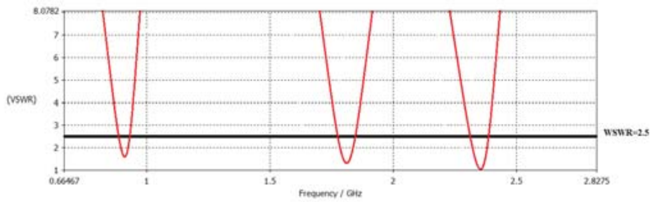
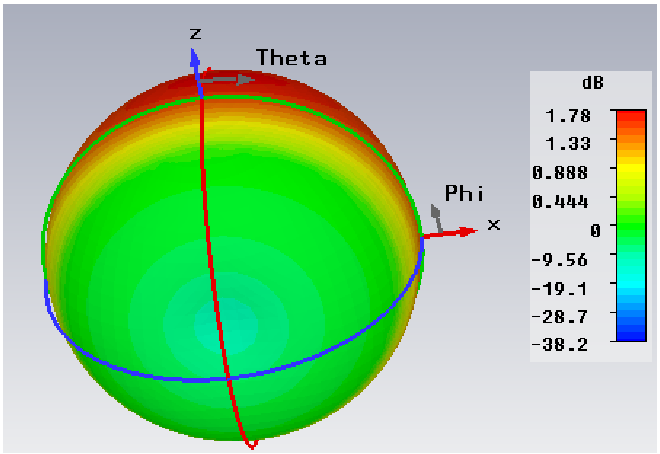


Fig.5. Simulated WSWR of the tri-band antenna

B. Radiation patterns and distribution of fields magnetic

The antenna gain pattern is shown in Figure 6. We can know from the figure that the gain will reach to 1.78 dB when F_1 is equal to 900MHz. The value will be 2.87dB when F_2 is equal to 1800MHz. And the value will come up to 3.47 dB when F_3 is equal to 2450MHz. We can see that the performance of the PIFA antenna can absolutely meet the requirements of practical application. The antenna's distribution of fields magnetic is shown in Figure 7. It's shown the distribution of field magnetic on the slots.



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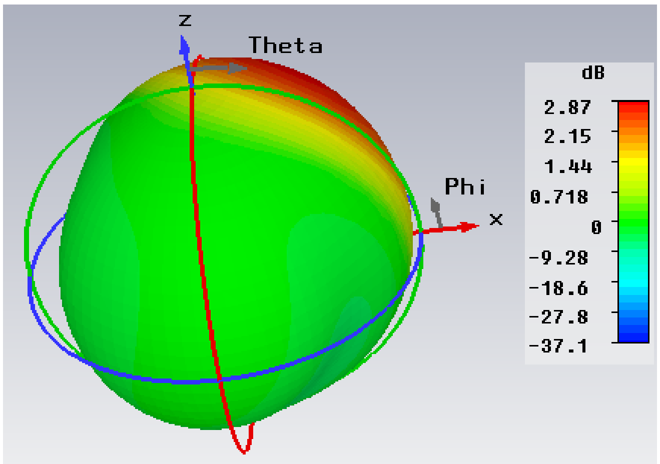
International Journal of Applied Engineering Research ISSN 0973-4562 Volume 10, Number 24 (2015) pp 43960-43965



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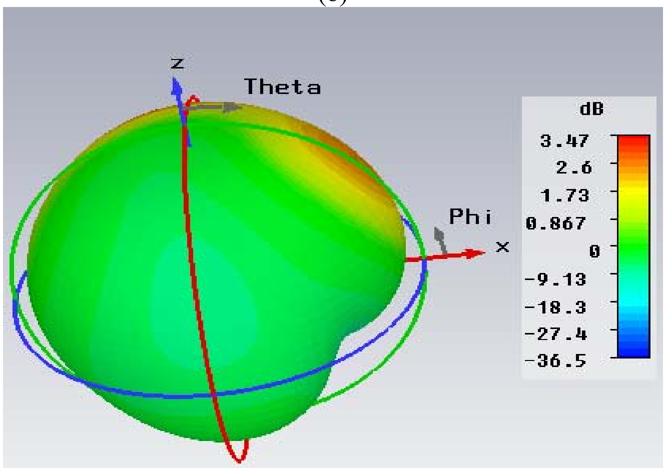
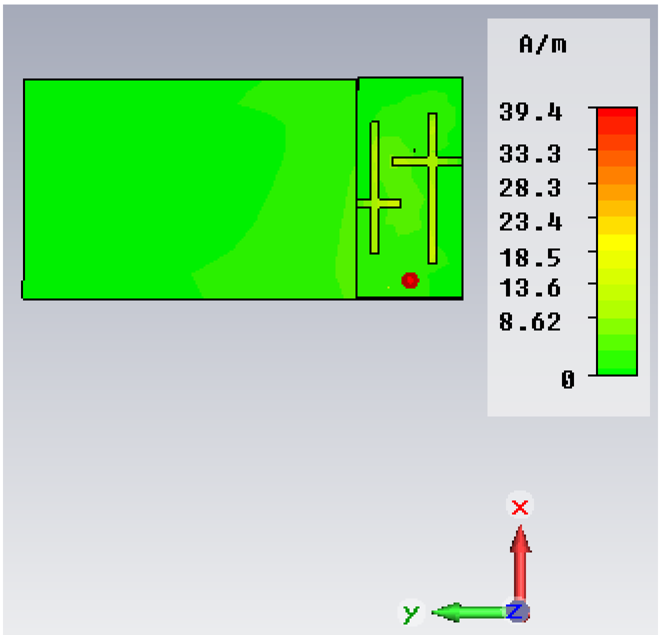


(c)

Fig.6. The calculated gain of the tri-band antenna (a) with 900MHz, (b) with 1800MHz, (c) with 2450MHz.



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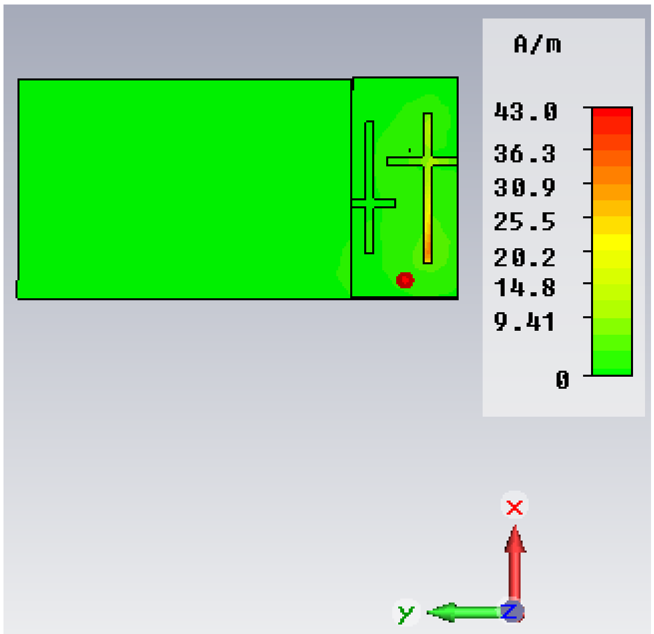

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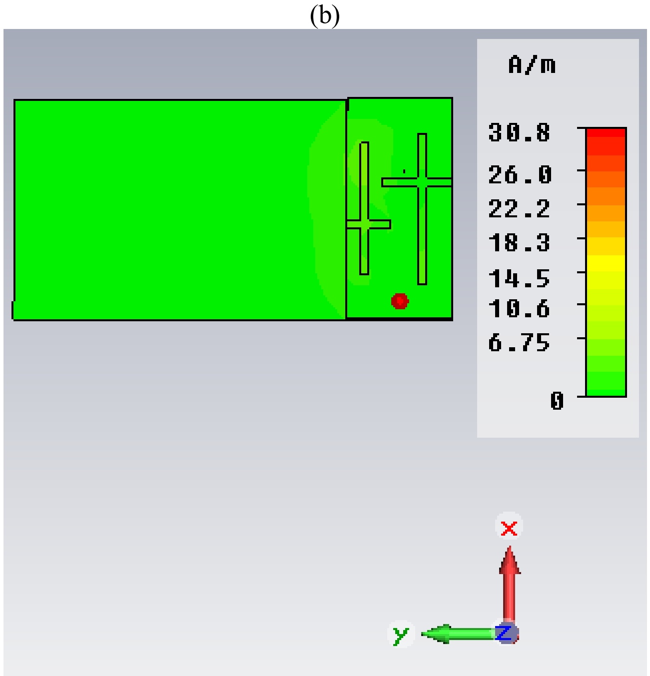


(c)

Fig.7. The calculated distribution of fields magnetic of the tri-band antenna (a) with 900MHz, (b) with 1800MHz, (c) with 2450MHz.

Improvement of triple-band PIFA antenna.

In this part, we insert a capacitor load in the slots. We have optimized the position of the capacitor load in such a way that we maximize the gain of the antenna. The Figure 8 shown the position of the capacitor load.

The figure 9 shown the return loss with and without capacitor load in slots.

We noted that the values of adaptation are modified so that in 0.9 GHz, we have the value-21.5 dB, in 1.8 GHz, we have the value-26 dB and in 2.45 GHz we have the value-21 dB.

The simulation results are stored in Table 1 of the performances triple-band PIFA antenna and a comparison with the results obtained without capacitor load.
We notice, in Figure 10 a level increase of the gain on three resonant frequencies with capacitive load. Make it, for the frequency 0.9 GHz, the gains cross 1.78 dB in 2.03 dB, for the frequency 1.8 GHz, the gains are thought of 2.87 dB in 3.23 dB and as the frequency 2.45 GHz the gains cross 3.47 dB in 5.32 dB.
According to the indicative table and comparison of results, we observe clearly that excites a significant improvement course at remarkable values of return loss, gain, performance, and distributions of the electromagnetic field and the surface current of antenna.

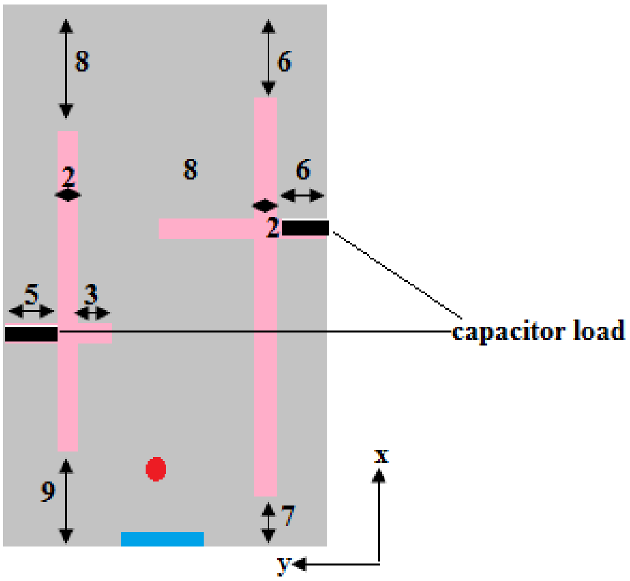


Fig.8. Radiating patch and capacitor load.

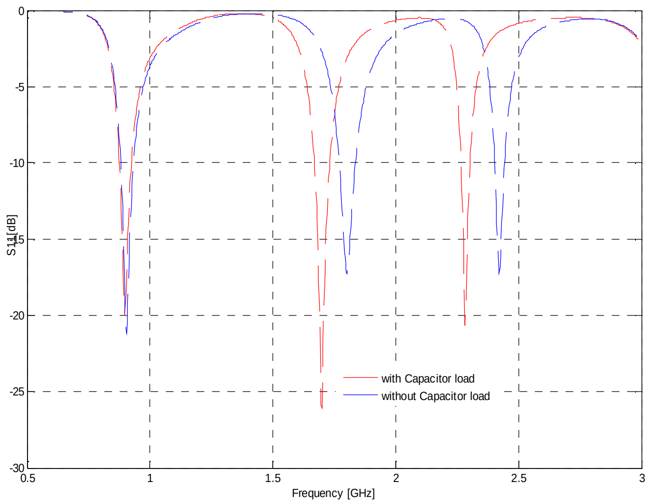
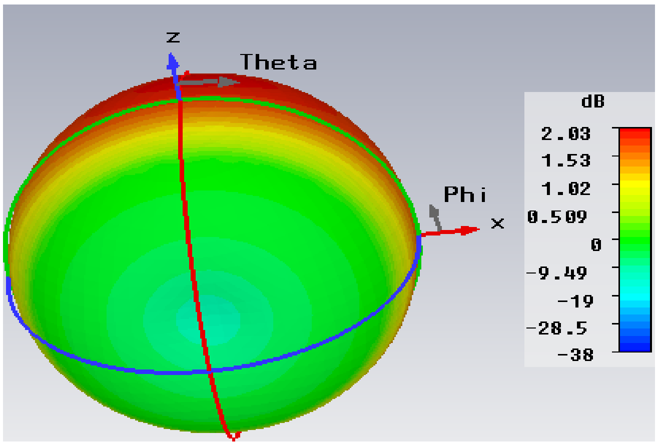
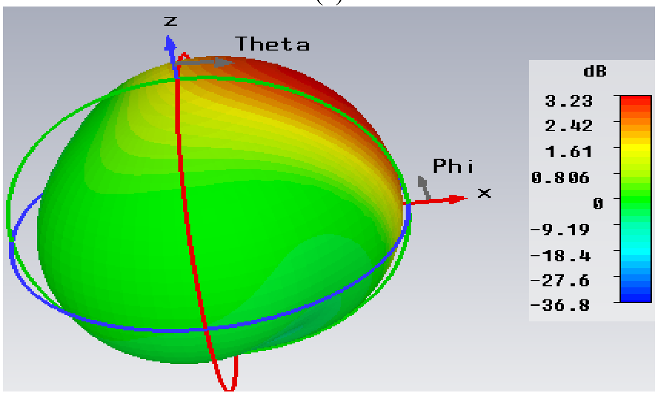


Fig.10.Simulated return losses of the tri-band antenna with and without capacitor load



(a)



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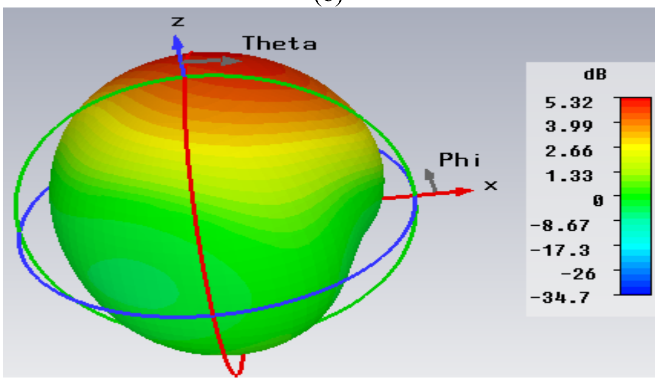

(c)

Fig.10. The calculated gain of the tri-band antenna (a) with 900MHz, (b) with 1800MHz, (c) with 2450MHz.

TABLE 1: Result of various performances parameters of PIFA antenna

(a) GSM Band

Parameters	**Value**	
	Without capacitor laod	With capacitor laod
Resonance Frequency [GHz]	0.9	0.9
Return loss [dB]	-21	-21.5
Gain [dB]	1.78	2.03
electromagnetic field [V/m]	5045	6234

Efficience η [%]	80	81
Surface current [A/m]	39.4	41.2

(b) DCS Band

Parameters	Value	
	Without capacitor laod	With capacitor laod
Resonance Frequency [GHz]	1.8	1.7
Return loss [dB]	-17.2	-26
Gain [dB]	2.87	3.23
electromagnetic field [V/m]	10266	10136
Efficience η [%]	83	89
Surface current [A/m]	43	42.7

(c) Bluetooth/Wifi Band

Parameters	Value	
	Without capacitor laod	With capacitor laod
Resonance Frequency [GHz]	2.45	2.32
Return loss [dB]	-17	-21
Gain [dB]	3.47	5.32
electromagnetic field [V/m]	9190	10536
Efficience η [%]	87	92
Surface current [A/m]	30.8	39.8

Conclusion

In this paper, we presented a new triple-band PIFA antenna for covering GSM 900MHz, DCS 1800 MHz and Bluetooth/Wifi 2450 MHz. After the optimization geometric parameters, we have applied the capacitor load in the slots, we reached a total radiation efficiency that exceeds 80% on all the frequency bands and a 2.03 total radiation gain dB for frequency 0.9 GHz, 3.23 dB for frequency 1.8 GHz to 1.8 GHz frequency and 5.32 dB for the 2.45 GHz frequency. According to this design, we understand the working principle of the multi-band antenna good foundation for future research.With the growth of new demand for mobile phone applications, such multi-band mobile phone antenna has a huge potential demand

Acknowledgment

I thank Mr Ali Gharsallah, my thesis Director, which encourages me to carry out this work with its instructions.

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