# A Comprehensive Simulation Study of Dual band Planar Inverted-F Antenna

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**Abstract – This paper presents a comprehensive theoretical and simulation study of dual band Planar Inverted-F Antenna (PIFA) involving major parameters which may affect the PIFA characteristics. It is found that characteristics of PIFA are affected by a various parameters including the length, width position and height of the top plate, ground plane dimensions, widths and position of shorting pin/plate and width and position of feeding pin/plate. In this paper some of the important parameters like width of feed plate, width of shorting plate, dimensions of top plate and dimensions of slot are studied using simulation software under the multiband antenna concept. These results are very useful for Designing multiband Planar inverted-F antennas.**

**Index Terms – Planar inverted F antenna, Multiband antenna, parametric study**, **Low profile antenna.**

## 1. INTRODUCTION

For wireless portable devices and mobile communication devices, the Microstrip Patch Antennas are preferably selected due to their low profile characteristics, low coast, easy fabrication and portable structure. But still they have the area to improve their bandwidth and to reduce their size, to make these more compact. Thus, Planar Inverted-F Antennas (PIFA) has come into interest.

The Planar Inverted-F Antenna (PIFA) can be observed as evolved from two well-known antennas, namely microstrip patch antenna and quarter-wavelength monopole antenna. Now, PIFA is widely used in handheld and mobile applications due to its attractive features such as low-profile, lightweight, simple design, low-cost, conformal nature ,low specific absorption rate (SAR) and good performance [1-4]. PIFA is also considered as one of the strong candidates for multiple input multiple output (MIMO) systems [5], [6].

From the literature, it is found that the characteristics of PIFA are affected by many parameters like dimensions of ground plane, the width, length and height of top radiating plate, the position of PIFA on ground plane, width of the feed plate, width of the shorting plate etc. Various parametric analysis are there in literature [7]. In this paper a comprehensive simulation study of the effects of following parameters in the bandwidth and resonating frequency of the dual band PIFA is carried out.

1. Dimensions of the top radiating plate
2. Dimensions of the slot
3. Width of the feed plate
4. Width of the shorting plate.

The remainder of this paper is organized as follows. Section 2 discusses the related works in the literature. Basic structure of dual band PIFA under study and its basic design equations are presented in section 3, which is followed in Section IV by simulation study of effects of various parameters on resonant frequency and bandwidth of PIFA and its results. Section V presents our conclusions.

## 2. RELATED WORK

The present research works in Planar inverted F antenna technology are mainly focused in the following areas: 1) Theoretical and practical Study of various characteristic and parameters of PIFA 2) Bandwidth enhancement of PIFA, Multi band operations and miniaturization. 3) Use of PIFA as an array element. 4) Electromagnetic interaction of PIFA with user’s hand and body.

The inherent narrowband property of the PIFA can be improved by various methods. To widen the bandwidth, one of the simple methods is increase the height of the PIFA [8]. But it is not a practical solution in many cases as it increases the overall size of the antenna and hence size of device. Size of the ground plane, position of the top plate on the ground plane also affects bandwidth. When radiating plates placed near the edges of the ground plane, PIFA gives maximum bandwidth [9]. Other methods are changing the feed and shortening plate/pin [10] and adding parasitic elements [11].

Human body interaction of PIFA is a hot topic in literature. It is observed that the characteristics of PIFA are slightly changed when interact with human body [12]. The comparison of SAR values of PIFA with common type handheld antennas like helical, patch and monopole antenna shows that PIFA has low SAR value [13].

## 3. ANTENNA CONFIGURATION

For this study, we design a dual band antenna which works on frequencies 1.57 GHz and 3.5 GHz. Design of 1.5 GHz is based on the following basic equations from [3].

$$f_c = \frac{c}{4(W_p + L_p)} \quad (1)$$

Where $f_0$ the operating/resonant frequency, c is is the speed of light, $W_p$ is the width, $L_p$ is the length of the radiating plate of the PIFA.

$$f_0 = \frac{c}{3W_p + 5.6L_p + 3.7h - 3W_f - 3.7W_s - 4.3L_b - 2.5L_s} \quad (2).$$

where $W_p$ is the width, $L_p$ is the length of the of radiating plate, h is the height of the PIFA, $W_f$ is the feed width , $W_s$ is the shorting plate width, $L_b$ is the the horizontal distance between shorting plate and feed plates , $L_s$ is the distance between the shorting plate and the edge of top plate.

For creating second resonant frequency, a slot is made in the radiating plate. The total length of the slot is designed as half wavelength of the second resonating frequency. The structure of the proposed antenna after optimization for adjusting the resonant frequency is shown in the two figures below. Figure 1 shows the three dimensional view and figure 2 show the top view of the proposed dual band PIFA.

The dimensions of the dual band antenna are shown in the table 1.

| Parameter | Value(mm) | Parameter | Value(mm) |
|---|---|---|---|
| $L_g$ | 50 | $W_f$ | 2.5 |
| $W_g$ | 35 | $W_s$ | 2 |
| $L_p$ | 23 | $L_1$ | 10 |
| $W_p$ | 18 | $L_2$ | 15.2 |
| Height | 5.9 | | |

Table 1: Dimensions of the Dual band PIFA

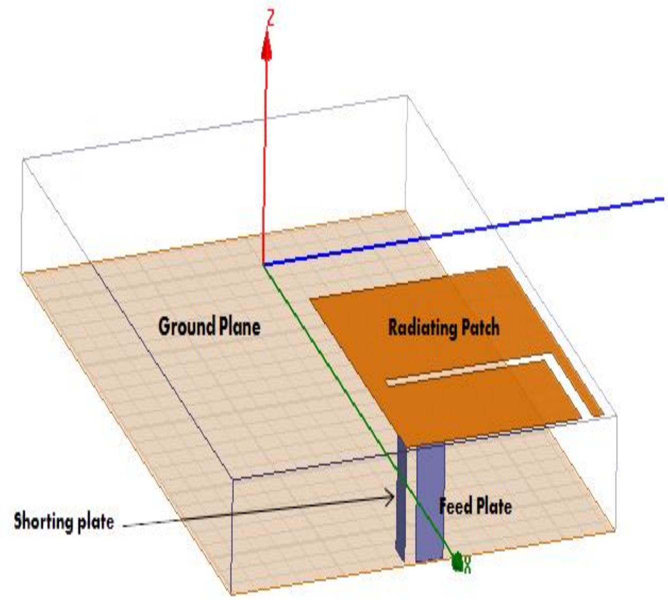


Figure 1: Three Dimensional view of the dual band antenna

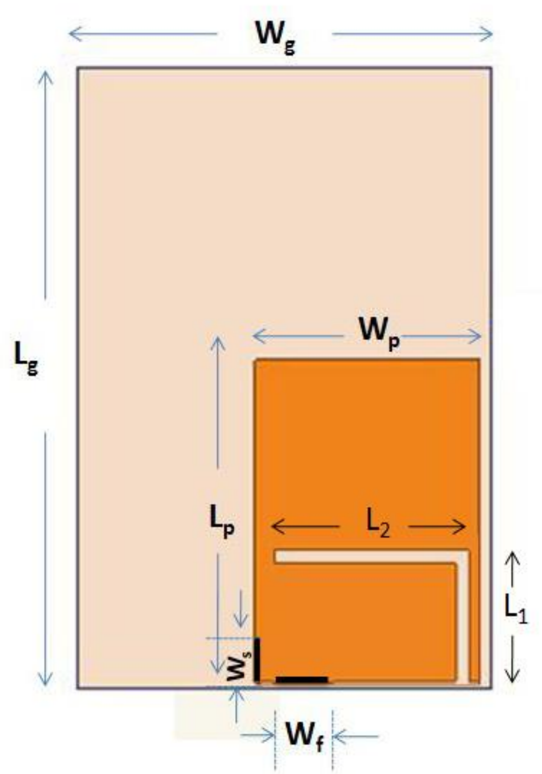


Figure 2: Top view of the Dual band antenna

## 4. SIMULATION STUDY

The procedure adopted for this simulation study is that only one parameter is changed at a time while all other parameters are held constant to observe its effects on the PIFA characteristics. The operational frequency ranges from 1 GHz to 4 GHz is considered and use Finite Element method for simulation study.

### 4.1 Dimensions of the top radiating plate

First, changes are made in the length and width of the rectangular top plate and their effects are noted on the characteristics of PIFA, especially in resonant frequency and bandwidth. The length of the top plate is varied from 21mm to 26mm with an increment of 1mm. The simulated results are shown in the figure below

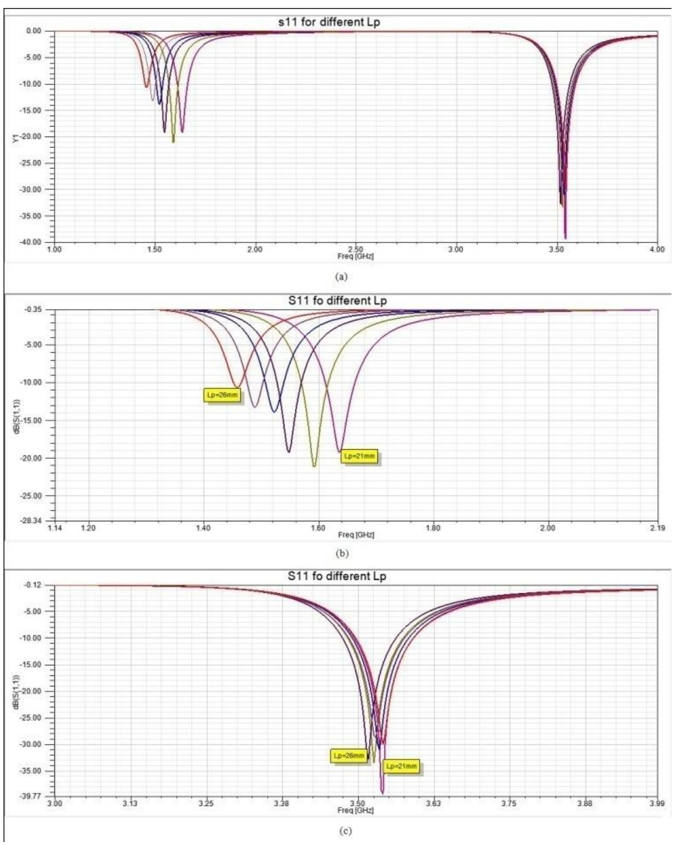


Figure 3: S11 for different values of Lp. (a) effect on dual band , (b) close-up view of effect on first 1.5GHz band and (c) Close up view of effect on second band 3.5GHz

PIFA is a quarter wavelength antenna, so increase in length or width of top radiating plate will cause a decrease in resonant frequency and vice versa. It is confirmed from the simulation result also. As we know that the dimension of the top radiation plate decides the first resonating frequency, the resonating frequency of first band (1.5GHz) is seriously affected by change in dimensions of top plate while only very small changes in the second resonating frequency.

The Bandwidth of the both the bands are not affected by the changes in dimensions of the top radiating plate.

### 4.2 Dimension of the slot

We know that the slot on the top radiating plate creates the second resonating frequency (3.5GHz).To study the effect of length of the slot in the resonating frequency and bandwidth of PIFA , the length $L_2$ is varies from 10.5mm to 15.5mm with an increment of 1mm. The simulation results are shown below in terms of $S_{11}$ versus frequency.

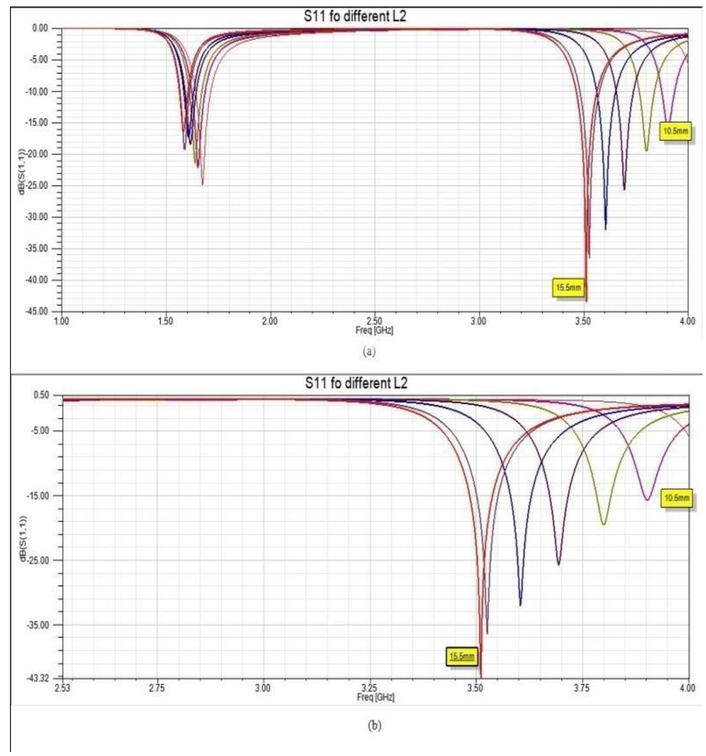


Figure 4: SLY for different ALL. (a) Effect on both band, (b) effect on second band (close up view)

From the results, it is clear that the length of slot decides the second resonant frequency. As length of the slot $L_2$ increases, the resonating frequency decreases and band width remains approximately same. The $L_1+L_2$ will decide the second resonating frequency.

### 4.3 Width of the feed

Now, to study the effect of width of the feed plate, varied the feed width $W_f$ from 1.5mm to 4mm with an increment of 0.5mm. The results in terms of $S_{11}$ are shown below figure.

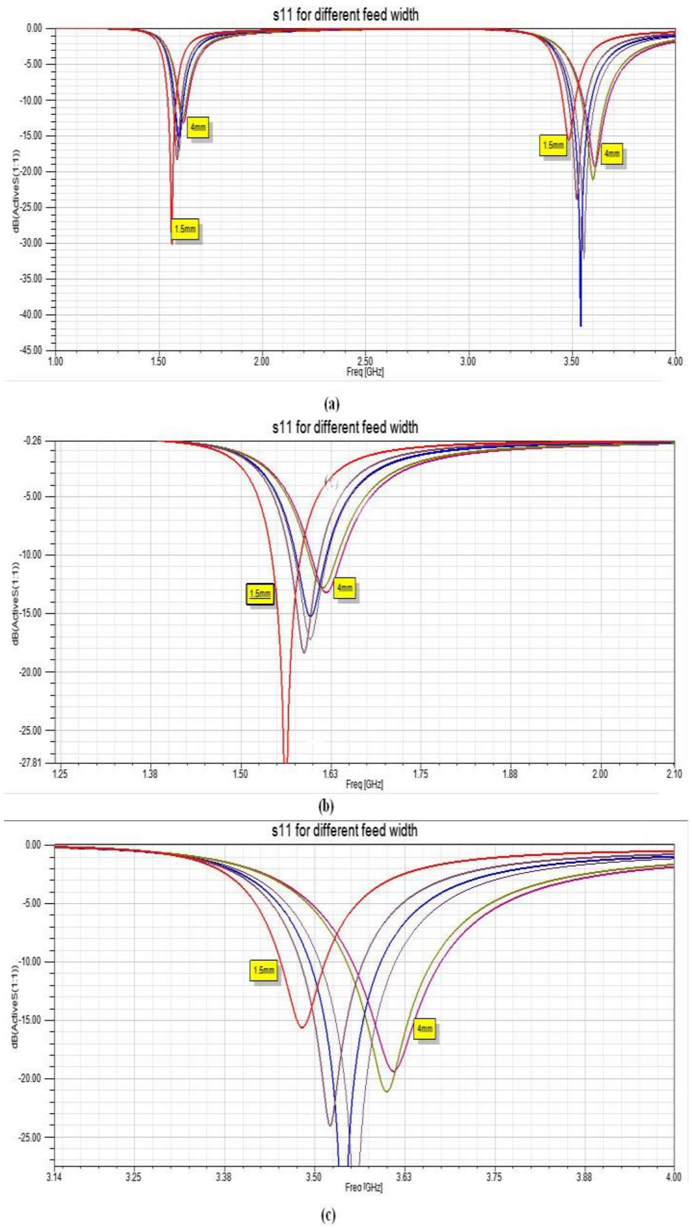


Figure 5: S11 for different feed width. (a) Effect on entire frequency range, (b) effect on first band, (c) effect on second band (3.5GHz)

From the results, we can understand that, as width of the feed increases the resonant frequency on both bands are slightly increases. But, the bandwidth of the antenna significantly increases with increase in feed width. The bandwidth enhancement is more dominant in second band than first band.

4.4 Width of the shorting plate

Last parameter we considered for this study is width of the shortening plate. The width of shorting plate is varied from 1.5mm to 4mm with an increment of 0.5mm. The results are shown in the following figures.

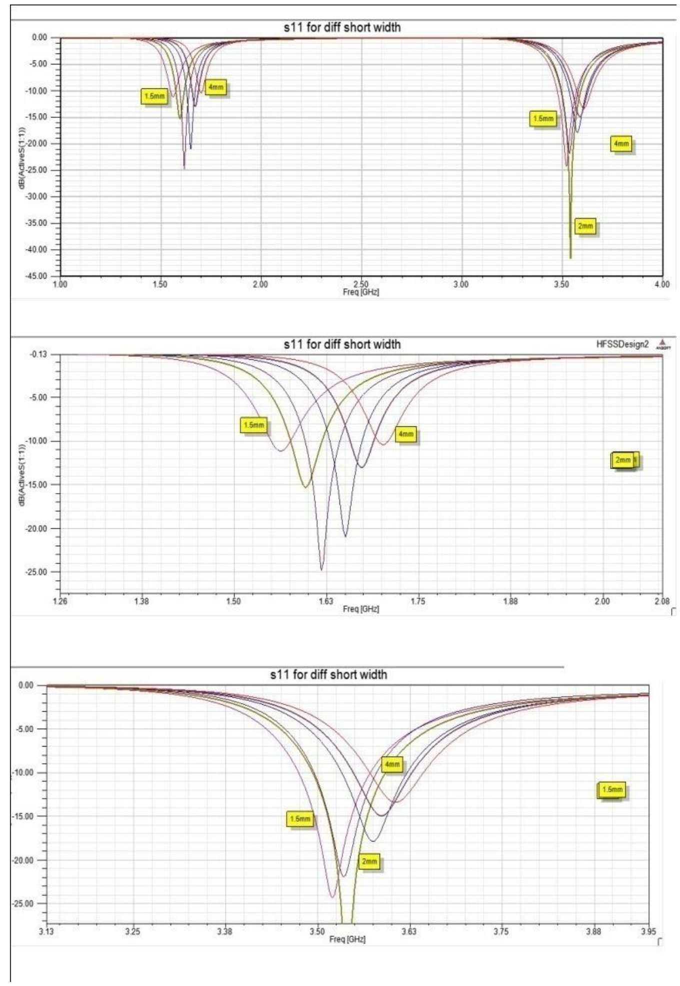


Figure 6: S11 for different shorting plate width. (a) Effects on both bands, (b) effect on 1.5GHz band, (c) effects on 3.5GHz band.

The width of shorting plate is affected both the bands. From the above results, it is cleared that as shorting plate width increases, the resonating frequency on both the bands are slightly increasing. As shorting plate width increases, up to 2mm, the band width and the reflection coefficients are increases and after 2mm, bandwidth and reflection coefficients are decreases. So good performance needed the shorting plate

## 5. CONCLUSION

We have shown that the Planar inverted F antennas characteristics are affected by many parameters. The conclusions are summarized as follows:

- By increasing the dimensions of the top radiating plate, the resonant frequency decreases. In the case of dual band antenna, changes in dimensions of the top plate are mostly affected in the lower frequency bands.

- By increasing the width of the shorting plate / feed plate, the resonant frequency decreases in both bands.
- The width of the feed plate is significantly affected the bandwidth of the PIFA. As feed plate increases the bandwidth of the PIFA also increases. The increase in bandwidth is more in higher frequency band.
- The width of the shorting plate is affected on resonant frequency and bandwidth of the PIFA. To get maximum bandwidth, feed width must be an optimum value.
- The resonant frequency of higher band is decides by the length of the slot in the radiating patch.

## REFERENCES

[1] Hirasawa, Kazuhiro, and Misao Haneishi, eds. *Analysis, design, and measurement of small and low-profile antennas*. Artech House on Demand, 1992.

[2] Balanis, Constantine A., ed. *Modern antenna handbook*. John Wiley & Sons, 2011.

[3] P. S. Hall, E. Lee and C. T. P. Song, "Planar Inverted-F Antennas, Chapter 7," In: by R. Waterhouse, Ed., *Printed Antennas for Wireless Communications*, John Wiley & Sons, Hoboken, 2007.

[4] Y. Huang and K. Boyle, "Antennas: From Theory to Practice," John Wiley & Sons, Hoboken, 2008.

[5] Y. Gao, C. C. Chiau, X. Chen and C. G. Parini, "A Com- pact Dual-Element PIFA Array for MIMO Terminals," Loughborough Antennas & Propagation Conference, Loughborough, 4-5 April 2005.

[6] Y. Gao, C. C. Chiau, X. Chen and C. G. Parini, "A Com- pact Dual-Element PIFA Array for MIMO Terminals," Loughborough Antennas & Propagation Conference, Loughborough, 4-5 April 2005.

[7] Chattha, Hassan Tariq, et al. "An empirical equation for predicting the resonant frequency of planar inverted-F antennas." *Antennas and Wireless Propagation Letters, IEEE* 8 (2009): 856-860.

[8] Liu, Duixian, and Brian Gaucher. "The inverted-F antenna height effects on bandwidth." *Antennas and Propagation Society International Symposium, 2005 IEEE*. Vol. 2. IEEE, 2005.

[9] Chattha, Hassan Tariq, et al. "A comprehensive parametric study of planar inverted-F antenna." (2012).

[10] Chattha, Hassan Tariq, Yi Huang, and Yang Lu. "PIFA bandwidth enhancement by changing the widths of feed and shorting plates." *Antennas and Wireless Propagation Letters, IEEE* 8 (2009): 637-640.

[11] Chattha, H. T., et al. "Further bandwidth enhancement of PIFA by adding a parasitic element." *Antennas & Propagation Conference, 2009. LAPC 2009. Loughborough*. IEEE, 2009.

[12] Khodabakhshi, Hamid, and Ahmad Cheldavi. "Numerical analysis of human head interaction with PIFA antennas in cellular mobile communications." *Progress In Electromagnetics Research B* 22 (2010): 359-377.

[13] Faruque, MR Iqbal, Mohammad Tariqul Islam, and Norbahiah Misran. "SAR analysis in human head tissues for different types of antennas." *World Applied Sciences Journal* 11.9 (2010): 1089-1096.

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