Multiband Planar Inverted F Antenna (PIFA) for ISM, WLAN and WiMAX Applications

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Abstract. This paper presents a new design of a multi-band inverted F antenna structure (PIFA) fed by a coaxial line. The design tool is the CST-MW software which uses the finite element method. To create new resonances frequencies it is necessary to insert slits of various forms on the radiation element. The final validated circuit is designed to operate in the Industrial Scientific and Medical (ISM 2.4 - 2.5GHz), Wireless Local Area Network (WLAN 5.15 – 5.35 GHZ) and Worldwide Interoperability for Microwave Acces (WiMAX 3.30 – 3.80). Obviously, it has been found that the radiation patterns of the antenna shown are similar to the bidirectional radiation pattern. For simulated The properties of the antenna, such as return losses and radiation patterns, we used CST-Mw Studio.

Keywords: *PIFA antenna, multibands antennas, slottedPIFAs, Simulation.*

1 Introduction

Currently, it requests wireless communication system technologies, which have the following attributes compact size, low profile, multi-band, high-bandwidth, etc…. In order to response the rapidly growing demand, an antenna should be responsible and operate in many frequency bands. Recently, multi-band antennas developments were improved thanks to the notion PIFA. Planar Inverted F Antenna (PIFA) is a linear Inverted F antenna (IFA) [1]. To increase the bandwidth and resonance frequency, the radiator element must be replaced by a plate. The reduced radiation behind the PIFA improves antenna performance in terms of gain and minimizes the wave produced due to power absorption [2-4]. We have a maximum gain in terms of polarization states like horizontal and vertical. The bandwidth can be adjusted if changing the height, length and width of the ground plane. To decrease the quality factor and to boost the bandwidth, many slits can insert in the ground plane. In medical applications, the main objective is to reduce the maximum size of the PIFA [5].

2 Planar Inverted Antenna F (PIFA)

Planar Inverted F antenna is developed from mono pole antenna. Inverted L is realized by folding down the mono pole in order to decrease the height of the antenna at the same time maintaining identical resonating length [6]. When feed is applied to the Inverted L, the antenna

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appears as Inverted F. The thin top wire of Inverted F is replaced by planar element to get the Planar Inverted F antenna. This sequence is clearly observable in Fig 1. [7-9]

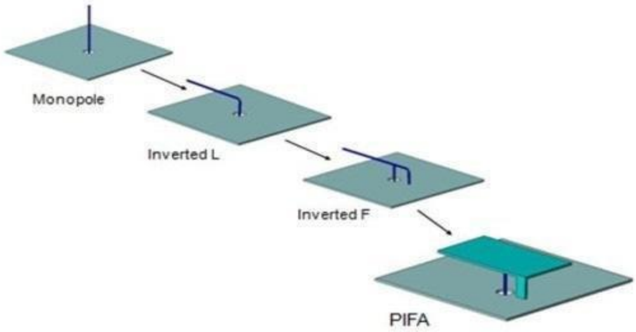


Fig. 1. PIFA from monopole

2.1 Pifa Design

PIFA consists of ground plane, radiating patch above the ground plane and shorting plane. A coaxial probe feed is given between the ground plane and patch element. Top radiating patch plane is folded at one edge of a patch and shorted to the ground plane to decrease the antenna length as shown in Fig 2 [10-12]. The size of the patch and resonating frequency can be determined by the following equations:

$$L_p + W_p - W = \frac{\lambda}{4} \tag{1}$$

$$f_r \times \lambda = \frac{C}{\sqrt{\varepsilon_r}} \tag{2}$$

$$f_r = \frac{C}{4\left(L_p + W_p - W\right)\sqrt{\varepsilon_r}} \tag{3}$$

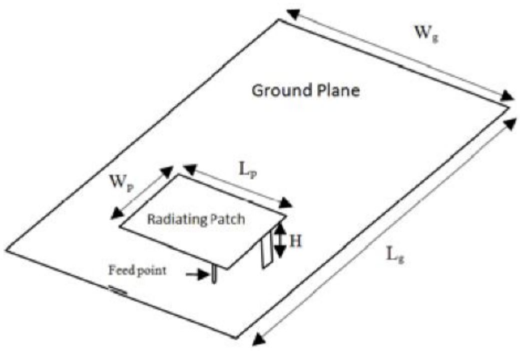


Fig. 2. Basic PIFA

Where Lp = length of the patch, Wp = Width of the patch, C = Velocity of light, εr = dielectric constant, ß = wavelength. PIFA has moderate (or) high gain in both horizontal and vertical polarization. Generally, most of the wireless systems use vertical polarization. Even if transmitter antenna polarization is not known, still the signal is received with good strength. When antenna orientation is not fixed, a signal with good gain (greater than 10 dB) is received and signal strength is calculated by summing up the horizontal and vertical components [13-15].

2 Antenna Description

The design of the proposed antenna is shown in Fig 3. It consists of patch plane, ground plane, shorting plate and feeding post connected to the ground plane. Between dielectric medium and patch plate, air is placed. Resonating frequency can be calculated if the initial patch and shorting pin sizes are known using equation (3).

The dimensions of PIFA are 50×46 mm^2 and are located 5 mm above the printed circuit board. The printed circuit board layer has a relative permittivity of 4.4 (FR4_epoxy) of size 93×60×0.5 mm^3. To provide an RF mass, the PCB is metallized on its back surface. Using optimization, PIFA is operating at 2.45 GHz, 3.6 GHz and 5.2 GHz resonance frequencies to cover ISM, WiMAX and WLAN bandwidths. The proposed antenna is powered by a coaxial probe. The U-shaped slot is introduced on the patch plane to obtain the multi-band.

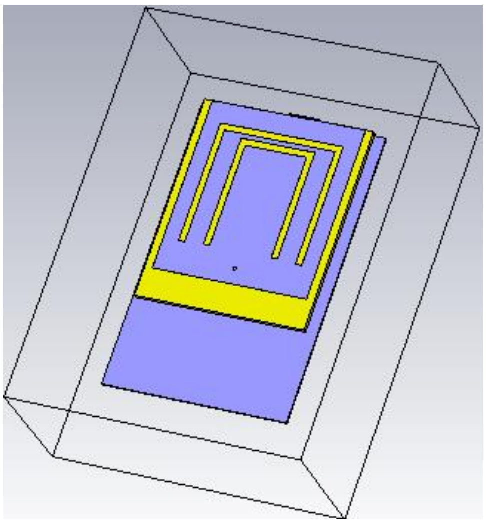


Fig. 3. PIFA design

Antenna geometry is shown in Table 1 and antenna description is shown in Table 2.

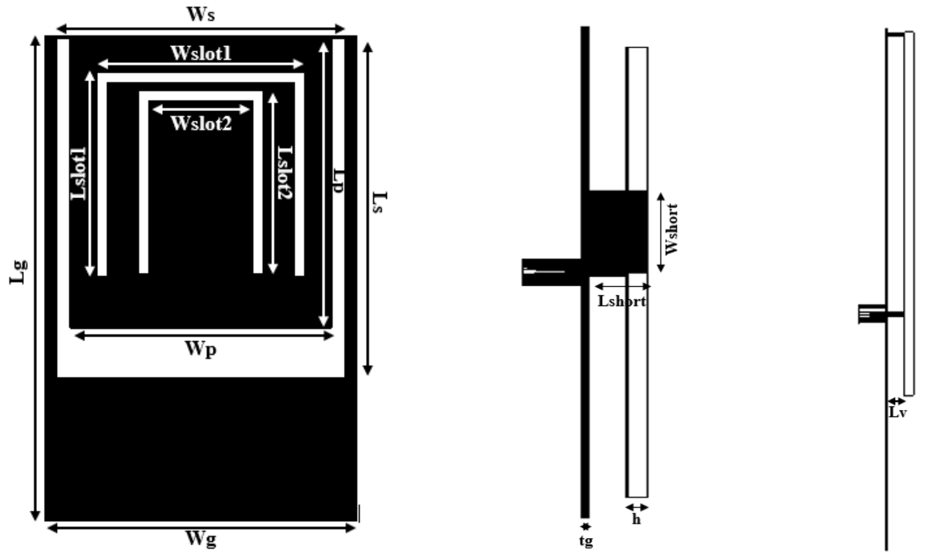
Table 1. Dimension of the proposed antenna

Parameter	Optimized Value (mm)
Ws	55
Ls	65
H	1.6
Wp	50
Lp	55.5
t	0.035
Wg	60
Lg	93
Lshort	5
tg	0.5
Wshort	10
Ri	0.5
Vcentre	18
Ro	1.637
Wslot1	40
Lslot1	39
Wslot2	24
Lslot1	35
Lv	3

Table 2. Antenna description

Shape	Rectangular
Frequency of operation	ISM WLAN WiMAX
Dielectric constant of the substrate	FR4 Epoxy (4.4)
Height of the dielectric substrate	1.6 mm
Feeding method	Coaxial
Gain	(2-7) dB

The dimensions of different slots are clearly mentioned in the front view of antenna as shown in Fig 4.



(a) (b) (c)

Fig. 4. Geometry of the proposed antenna: (a) front view, (b) top view, (c) side view

4 Simulation Results

The Planar Inverted F antenna was analyzed and optimized with the CST Microwave Studio. Since generally PIFA is a high frequency device driven model is used while designing antenna in CST Microwave Studio. The simulation results in all cases were swept over a frequency range between 2 and 7 GHz.

4.1 Return Loss

Reflection coefficient of an antenna is an important parameter in any antenna design analysis. It gives the measure of how much amount of power will be reflected back from the antenna. It should be kept as minimum as possible.

The simulated result is shown in Figure 5, as we can see we have reached the suitable frequency bands as ISM, WLAN and WiMAX.

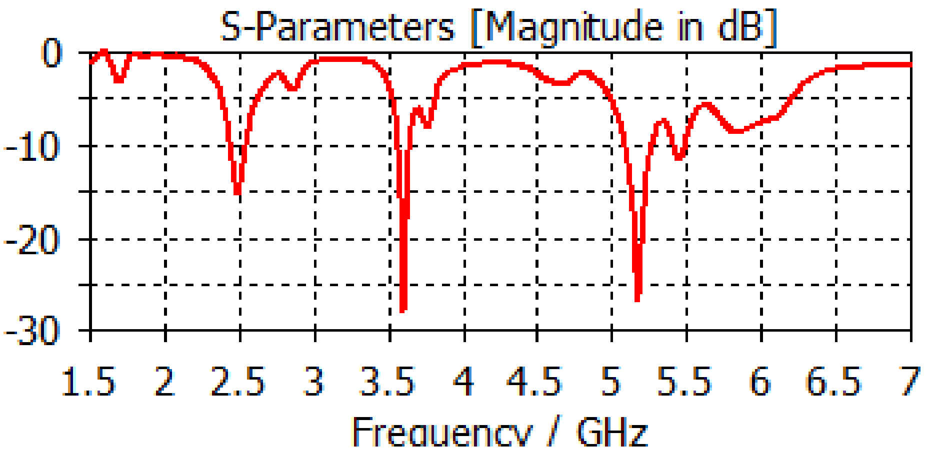


Fig. 5. Simulated Return Loss versus frequency

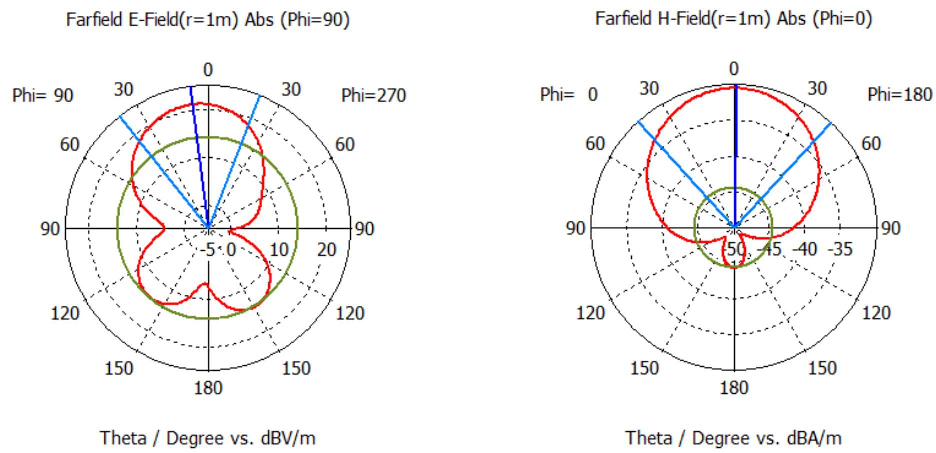
Table 3. Frequency bandwidth versus return-loss value

Frequency	**Return Loss in dB**
2.41 – 2.58 GHz	-15.26
3.51 – 3.69 GHz	-27.76
5.04 – 5.31 GHz	-26.62

4.2 Radiation Pattern

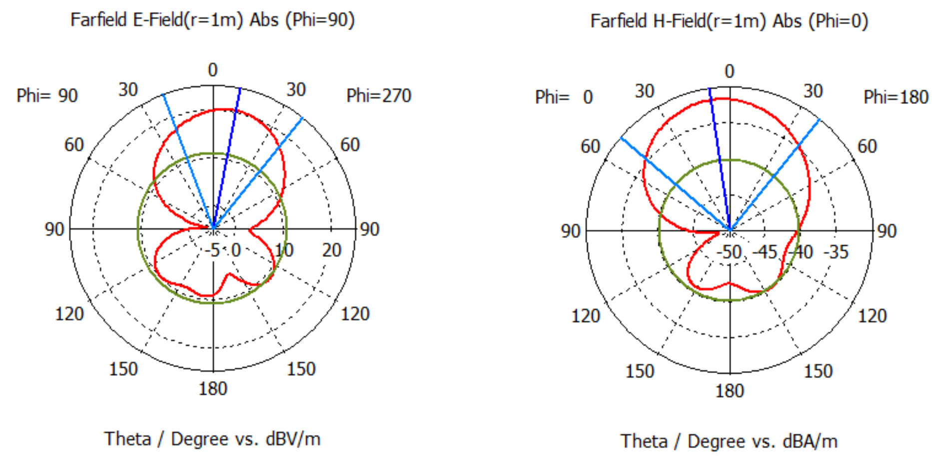
The radiation pattern of an antenna is used to describe the 3-dimensional radiation characteristics.

Figure 6, 7 and 8 presents the radiation pattern for different center frequencies, which give a stable radiation for different frequency bands.



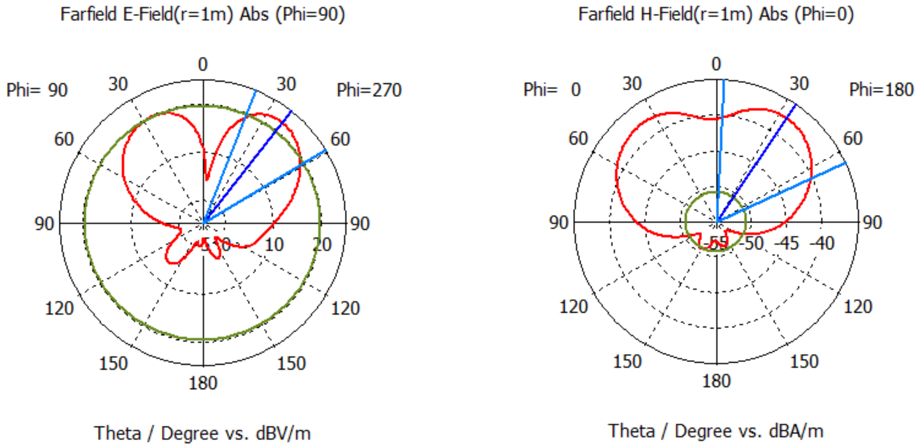
(a) (b)

Fig. 6. Radiation pattern of the proposed antenna at 2.45 GHz in the (a) E-plane and (b) H-plane



(a) (b)

Fig. 7. Radiation pattern of the proposed antenna at 3.60 GHz in the (a) E-plane and (b) H-plane



(a) (b)

Fig. 8. Radiation pattern of the proposed antenna at 5.20 GHz in the (a) E-plane and (b) H-plane

Figure 9, illustrates the variation of the gain versus frequency. After the simulation, we have obtained the gain 6.75dB at 2.45GHz, 5.58dB at 3.6GHz and 7.14dB at 5.2GHz.

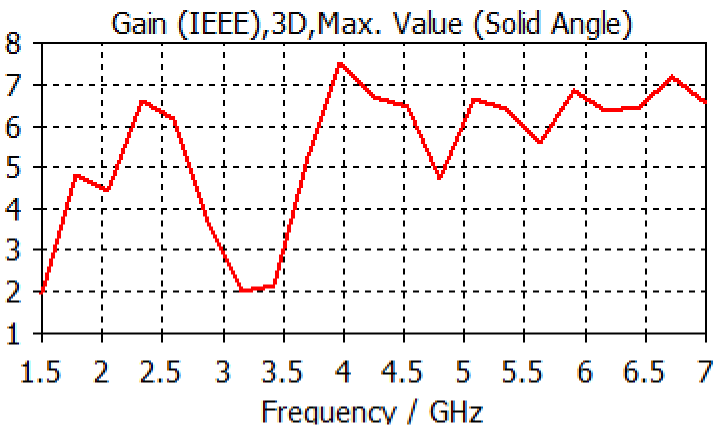
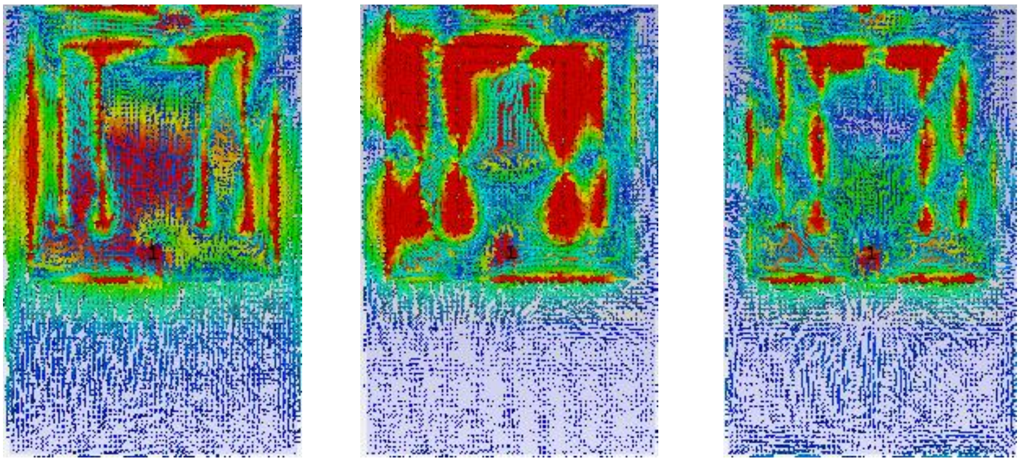


Fig. 9. Simulated gain of the proposed antenna

We present the simulated surface current distribution of the proposed antenna in the Fig. 10 at different frequencies.



(a) (b) (c)

Fig. 10. Simulated surface current distribution at (a) 2.45GHz, (b) 3.6GHz and (c) 5.2GHz

Conclusion

In this work, we have validated into simulation a Planar Inverted Antenna (PIFA) based on the use of a coaxial line. To validate this antenna structure, we have used CST-MW. The PIFA covers a bandwidth of 170MHz (2.41-2.58GHz), 180MHz (3.51-3.69GHz) and 270MHz (5.04-5.31GHz) and lower and higher bands with directivity of 7.22dB, 7.49dB and 8.24dB at lower and higher resonating frequencies 2.45GHz, 3.60GHz and 5.20GHz respectively. This antenna structure has a stable bidirectional radiation pattern and good input impedance matching with a significant bandwidth.

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