

Ultra Wide Band Planar Inverted F Antenna Design



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and Pooja Mukherjee

Abstract By incorporating a suspended metallic patch with two different slots and a shorting post as a support of suspension, an ultra wide band PIFA has been proposed which leads to an achievement of a gain greater than 11 dB in the operating frequency range 7.39–15.98 GHz with a ultra wide bandwidth of 8.53 GHz and over 95% fractional bandwidth. The width of the shorting post and the height of the patch from ground plane are optimised to 4 mm and 2 mm. respectively. The metallic patch is suspended above the ground plane with the help of the shorting pin. To secure a maximized return loss, the lumped port and the shorting post are placed at the edge. The rectangular and circular slot is optimally positioned on the patch for securing a high bandwidth.

Keywords Ultra wide band PIFA · Micro-strip patch · High gain

1 Introduction

In the modern era of miniaturization there is a requirement of designing a low profile antenna which yields optimum characteristics like wide bandwidth and high gain. PIFA is the most promising candidates in this regard. It provides small size, light weight, omni-directional radiation pattern, reasonable gain and acceptable bandwidth. It is a challenging task to acquire high gain and high bandwidth simultaneously for PIFA. In the recent reported works, PIFA operates in 4 bands by inserting U shaped slits on the patch [1] which causes a 55% size reduction. Liu et al. [2] reports size miniaturization of PIFA by employing hook-shaped slots at the edges of the radiating patch. Leelaratne et al. [3] presents compact PIFA antennas operating at mobile telephone bands which exhibits horizontal polarization sensitivity. A flat structured hexaband PIFA for mobile handset applications is proposed in [4] while an UWB PIFA working from 817–11.5 GHz is mentioned in [5] having return loss less

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than -6 dB. Broadband characteristics are achieved with two branchlined meander structured PIFA in [6]. The effect of dielectric constant of the substrate on return loss, impedance bandwidth, resonant frequency and gain are explored for a PIFA having dimensions $15.3 \text{ mm} \times 15.3 \text{ mm}$ in [7].

In this paper, a novel design of ultra wide band PIFA that exploits the frequency range of 7.39 GHz to 15.98 GHz with a high bandwidth of 8.53 GHz and a fractional bandwidth of 95.5% has been proposed. The design consists of a metallic patch having two different shaped slots which is suspended above the ground plane with the help of a shorting post of width 4 mm . One slot is rectangular in shape and the other slot is made by integration of a rectangular slot and circular slot which enhances the operating bandwidth of the antenna without perturbing its high gain characteristics in the radiation pattern. The gain of the proposed PIFA is about 5 dB which ensures low power loss and higher directivity in point to point communication systems.

2 Structure of the Proposed PIFA

The PIFA has been designed and analyzed using the following design equations. The length and width of the patch corresponding to the design frequency for high gain has been calculated based on the following equations.

$$l + w = \lambda/4 \quad (1)$$

when

$$w/l = 1, \quad l + h = \lambda/4 \quad (2)$$

when $w = 0$,

$$l + w + h = \lambda/4 \quad (3)$$

where

$\epsilon_r = 4.4$, the relative permittivity of FR4epoxy.

l is the top patch length.

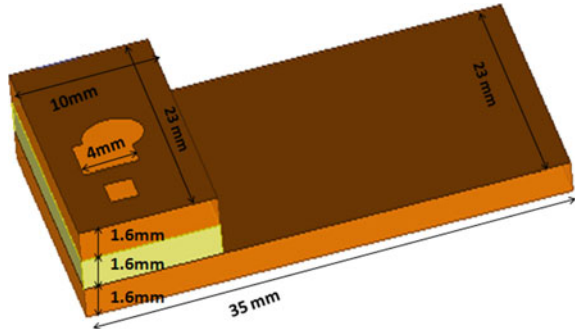
w is the top patch width.

λ is the wavelength corresponding to resonant frequency.

h is the height from the ground patch.

The input impedance of the antenna is controlled by the width 'w' of the patch of the antenna (Fig. 1). The gain of the PIFA can be increased by increasing the width. The resonating frequency is inversely proportional to the length l of the patch. The height of the patch from the ground plane has significant impact on the operating bandwidth and it is optimized to 2 mm for achieving a wide bandwidth. PIFA is widely used in wireless communication because of its feature that it exhibits moderate to

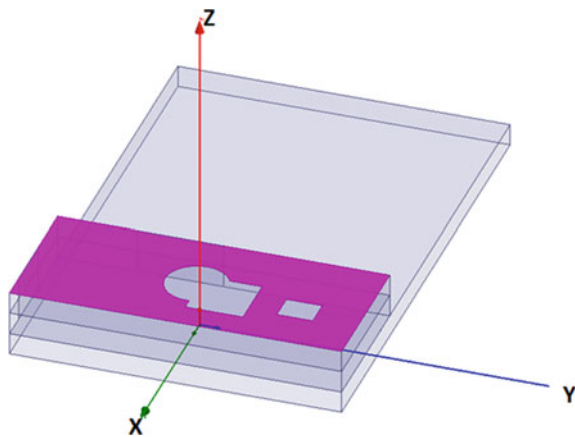
Fig. 1 Structure of the proposed PIFA



high gain values in both horizontal and vertical states of polarization. In addition to it, it possesses features like high efficiency and wideband characteristics.

The design of the proposed antenna is shown in Fig. 2. The proposed PIFA consists of the ground plane, metallic patch, lumped port and shorting post. The metallic patch is suspended in the air with the assistance of a shorting post. The metallic plate consists of two slots. One slot is the rectangular slot and other slot is made by the merging rectangular and circular slots. The slotted patch is etched on the FR4 substrate. The slots are the important elements in increasing the gain of the antenna as they assist in modifying the current distribution on the patch. The position of the shorting post and lumped port determines the frequency of operation of the antenna. The slots compel the current to flow around the impediments which increases the electrical path length. The slots thus increase the electrical dimensions which excites low frequency modes for enabling the antenna to resonate at lower frequencies. The slots are capacitively coupled for improvement in matching.

Fig. 2 Structure of the radiating patch



2.1 Analysis and Design

The physical dimensions of the ground plane are 10 mm × 23 mm. The shape and size of the ground plane is the important factor in determining the gain of the antenna. The physical dimension of the patch plane is 10 mm × 15 mm. The patch is formed on FR4 epoxy, a kind of dielectric material having a dielectric constant of 4.4. A dielectric substrate is important because it improves the electrical and mechanical stability. The dielectric material is employed to supply the displacement current which produces time varying Magnetic field (by Ampere’s Law). Dielectric materials also are helpful in reducing the dimensions of the antenna due to higher permittivity (Figs. 3 and 4). The length of the substrate below the bottom plane is 35 mm whereas the width of the substrate below the bottom plane is 23 mm. The space between the patch and

Fig. 3 Structure of the ground

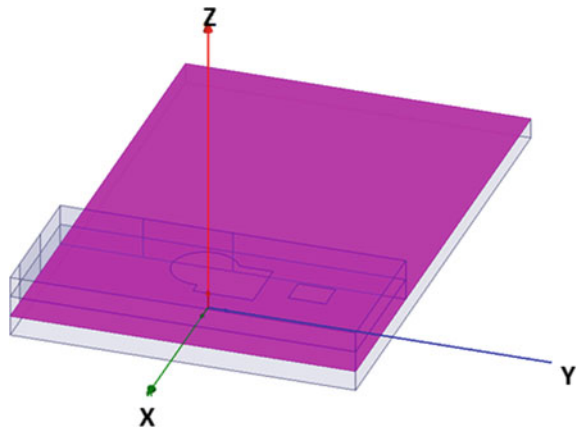


Fig. 4 Reflection Coefficient of the proposed PIFA

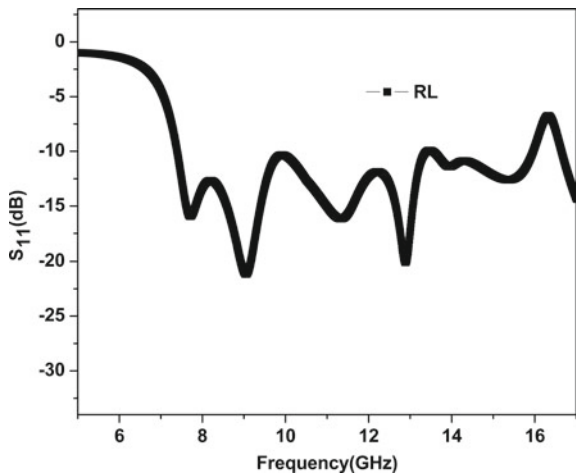
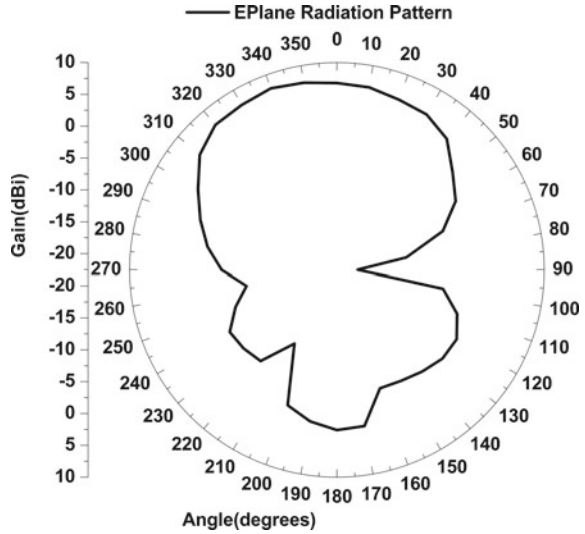


Fig. 5 Radiation Pattern at 9 GHz



the ground plane is 2 mm. The ground plane in this design has the dimension of 15 mm by 23 mm. The lumped port and the shorting post are substituted at the edge so that the return loss is maximized. The metallic patch is suspended in the air with a shorting pin. In the design it is shown by the air box above the ground plane. The dimension of the metallic patch is 10 mm by 23 mm. The bandwidth of the PIFA is affected by the position of the metallic patch and also the slots over it, above the ground plane. In this design a high bandwidth of 8.53 GHz is achieved which is ultra wide band and is ideal for mostly all kind of communication networks. The antenna is functioning in the frequency range of 7.39 GHz to 15.98 GHz. The gain of the antenna is 5 dB. The radiation pattern and gain of the proposed PIFA is analogous to that of a monopole antenna as shown in Fig. 5.

Antenna’s feed position is also a necessary parameter as the correct feed—position assists impedance matching. Usually, coaxial feed is used as the feeding port but in our design we have used lumped port of physical dimension 12 mm × 6 mm. The lumped port helps in finding the response of the antenna in terms of S-parameters which helps to determine its impedance matching and insertion loss. The radiation efficiency of the antenna is 102% in the operating bandwidth (Figs. 6 and 7; Table 1).

The lowest resonant frequency is determined by the altitude of the antenna and location of the closest edge of the short-circuited wall. The upper frequencies are adjusted by the width of the vertical wall. At the resonant frequency 9.4 GHz, maximum current distribution occurs on the patch due to electrical resonance.

Fig. 6 3D Polar plot of the proposed PIFA

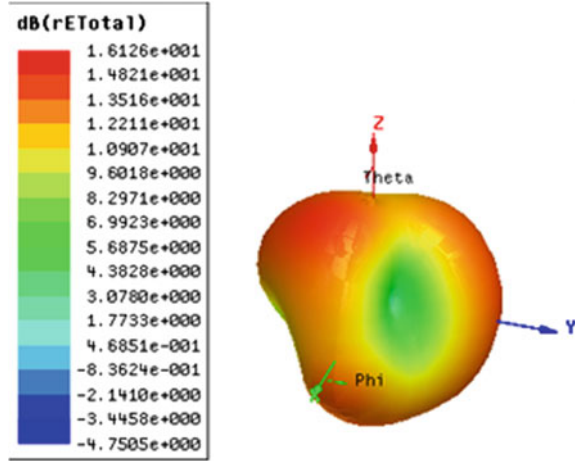


Fig. 7 Surface Current distribution on the patch at 9.4 GHz

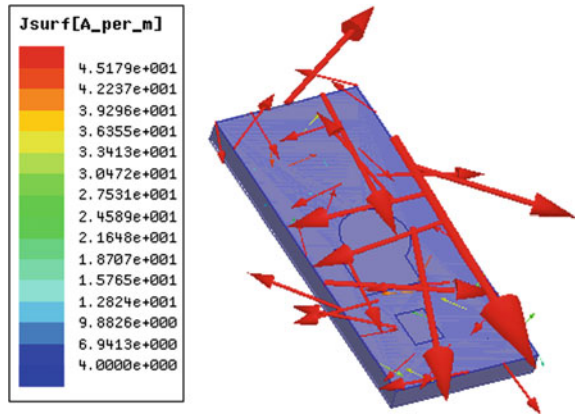


Table 1 Optimised Dimensions Of the PIFA Antenna

Parameters	Values
Patch length (l)	10 mm
Patch width (w)	23 mm
Lumped port position (lp)	12 mm
Lumped port width (lpw)	6 mm
Shorting post position (sp)	-2 mm
Shorting post width (spw)	4 mm
Length of the substrate below ground plane (lg1)	35 mm
Height of the Air box (h1)	1.62 mm

3 Conclusion

In this design two slots are formed on the patch namely a smaller rectangular slot and a slot which is made by uniting the areas of a rectangular slot and circular slot. The novelty of the proposed work lies in the design of the slot which is responsible for enhancing the bandwidth of the antenna by perturbing the electric field distribution on the patch. The proposed antenna exhibits a high gain which makes it suitable for modern communication systems.

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