Analysis And Simulation Of Low Profile Planar Inverted - F Antenna Design For WLAN Operation In Portable Devices

Zaw Htet Lwin, Su Su Yi Mon, Hla Myo Tun

Abstract: This paper presents a compact planar inverted–F antenna (PIFA) design for WLAN operation in portable devices. The proposed design has size of 8 x 21 mm and provides peak directive gain of 5.78dBi with the peak return loss of -33.89dB and input impedance of 50.28Ω. It covers a 10dB return loss bandwidth of 410MHz (2.37GHz – 2.789GHz). Its VSWR varies from 1.96 to 1.93 within the antenna return loss bandwidth. As the dimension of the proposed antenna is very small, the antenna is promising to be embedded within the different portable devices employing Wi–Fi applications. This paper includes the return loss as a function of frequency with varying the different parameters, VSWR, input resistance, radiation pattern and current distribution of the proposed antenna.

Keywords: PIFA; WLAN; compact antenna

I. Introduction

In recent years, the rapid development in wireless communication system leads to several growing demands with the designing of various portable devices which require low profile antenna. In order to satisfy these demands, Planar Inverted – F antenna (PIFA) and Microstrip antenna (MSA) are becoming popular for handling wireless devices. PIFA has been widely used in portable devices due to its compact, low profile configuration, ease of fabrication and favorable electrical performance. At present the demand of wireless local area network (WLAN) are increasing numerously worldwide, because they provide high speed connectivity and easy access to networks without wiring. The wireless fidelity (Wi-Fi) can provide a long operating range with a high data rate for mobile broadband wireless access, faultless internet access for wireless users becomes more popular. The wireless fidelity (Wi-Fi) operates in the 2.4GHz band (2.4GHz – 2.48GHz) and 5GHz band (5.15 – 5.35GHz, 5.47 – 5.735GHz and 5.725 – 5.875GHz) [1]. Planar inverted F antenna can be viewed as evolved from a quarter wavelength monopole antenna. In general it consists of a finite ground plane, a top plate element, a feed wire attached between the ground plane and the top plate and a shorting wire that is connected to the top plate from the ground plane. The antenna is fed at the base of the feed wire at the point where the wire connects to the ground plane. The addition of a shorting strip allows good impedance match to be achieved with a top plate that is typically less than λ/4 long. The resulting PIFA is more compact than a conventional half wavelength probe fed patch antenna [5]. According to the literature review, other patch designs for dual band operations have been proposed but these are large volume for portable devices. So, a compact PIFA for 2.4 GHz Wi-Fi operation in the portable devices is presented in this paper. The designed antenna is shorted to the ground plane by a plate, uses regular shapes and a high dielectric substrate under the radiating plate not above the ground.

II. Antenna Design

The design parameters for this antenna are the height, width and length of the top plate, the width and the location of the feed wire. In designing the compact PIFA antenna for 2.4GHz WLAN application, the possibility of increasing antenna bandwidth and maintaining the input impedance near about 50Ω and VSWR between 1 and 2 through the application bands with simplifying its structure are examined. To ascertain the effect of different loading on the antenna performance, parametric studies which are used to find out the optimal design are conducted. In our analysis, the copper conductor was assumed and the antenna was intended to be matched to 50Ω system impedance. Figure 1 represents the basic geometry of the PIFA. Here, one leg of PIFA is directly connected to the feeding and another leg is connected to the ground plane for shorting. The antenna is assumed to feed by 50Ω coaxial cable, with its central conductor connected to the feeding point and its outer conductor connected to the ground plane. For simulation FR4 with permittivity of ε_r =4.4, substrate thickness 1.58mm and the dimension of the ground plane are considered as 21 x 75 mm^2. Mathematically, PIFA antenna's size can be reduced by using factor of $\sqrt{\varepsilon_r}$. Therefore, if design uses a material with higher ε_r, that reduces the size of the PIFA which is a useful way to get a low profile antenna but that could affect the gain of the antenna as well. It is a big challenge to keep the efficiency without any effects when the small size is required. So, the PIFA dimensions which are used in this design were chosen after many simulations. These are based on the lowest value in return loss and the smallest size.

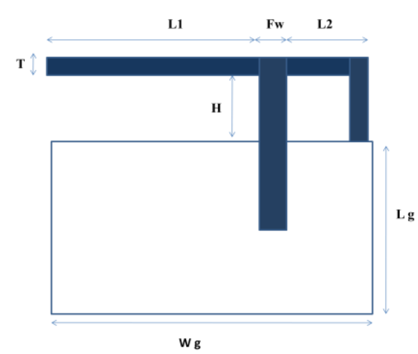

Figure 1. *Planar Inverted F Antenna*

The relation between the resonant wavelength and the resonant frequency can be determined by the equation :

$$\frac{\lambda_0}{4} = \frac{C_0}{4\,f_0 \times \sqrt{\varepsilon_r}}$$

Where C_0 is light of speed in space, f_0 is resonant frequency and $\mathcal{E}_{\square}$ is relative permittivity. The calculated resonant frequency is not very close to the desired frequency. By optimizing L1+L2 change, the resonant frequency will shift to upper or lower than the calculated resonant frequency. In fact, there is no equation to determine the resonant frequency for a PIFA that contains not only the patch dimensions but also the other parameters that can affect the antenna characteristics [6]. For this design, the author will make constant the patch dimensions that are the mean parameters can furnish the resonant frequency and we will vary undependably the others parameters (height of radiating plate H, spacing between the feeding and shorting mechanisms and the width of the feeding arm). The width of the feeding line can be calculated by the following equation:

$$Z_0 = \frac{87}{\sqrt{\mathcal{E}_r + 1.41}} \ln\left(\frac{5.98D}{0.8F_w + T}\right)$$

Where Z_0 means characteristic impedance, D is the dielectric thickness, F_w is the width of the feeding line and T is feeding thickness (1.37 mils for typical value). The miniaturization approaches are based on either geometric manipulation (the use of bend forms, meandered lines, PIFA shape, varying distance between feeder and short plate) or material manipulation (loading with a high dielectric material, limped elements, conductors, capacitors, short plate or the environment characteristics (ground plane dimensions). Our attempt was to reduce the size of the antenna without reducing the antenna performances for 2.4GHz Wi-Fi operation in the portable devices. Figure 2 shows the effects of length (L1) on the return loss as a function of frequency on the PIFA of figure1.

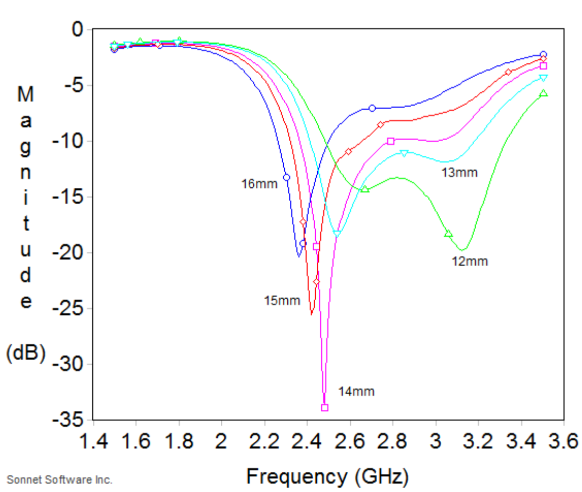

Fig: 2. *Return loss (dB) as a function of frequency with the different length L1 of the antenna structure of Fig:1.*

From the simulation result shown by figure 2, the optimal length is 14mm because it gives the high value of return loss (-33.89dB). Now maintaining the length of the top radiator we continue our advance analysis on the height of the radiator which is the distance between the top plate and the ground plane. In order to eliminate the effects of the ground plane effects, the patch on the edge of the ground plane at a height varying from 4.75mm to 11.25mm is placed. Figure 3 represents the variations of return loss for different values of H of PIFA. From the analysis on figure 3 for the optimized value of H, we can see that when the value of H=7.75mm, the antenna provides maximum return loss at operating band.

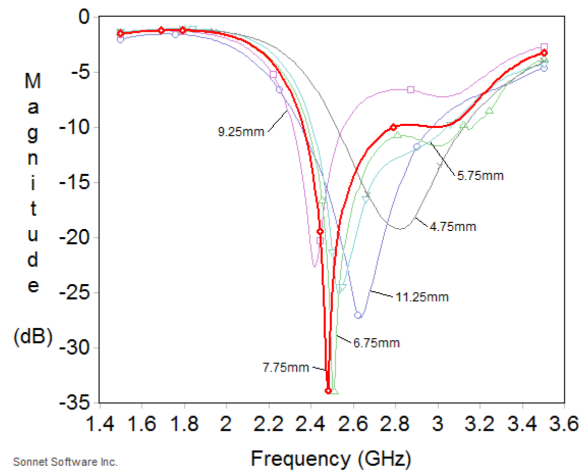

Fig: 3. *Return loss (dB) as a function of frequency with the different value of H of the antenna structure Fig: 1.*

Figure 4 shows the effects of spacing between feeding arm and shorting arm. We will vary the value of spacing form 1.75mm to 4.25mm. From the figure 4, the value of 3.25mm is the best result for optimized value because the resonant frequency is the very close to the desired frequency. Figure 5 shows the effects of the feeding width on the return loss when L_1 = 14mm, L_2 = 4.25mm and H=7.75mm. According to the simulation result, the value of 3.25mm is the good impedance match for the design.

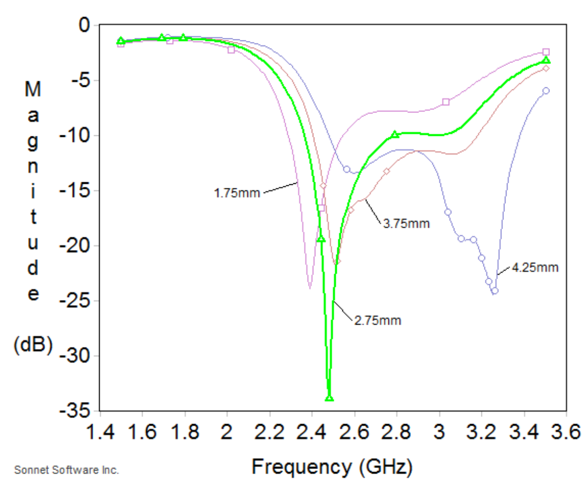

Fig: 4 *Return loss (dB) as a function of frequency with the different spacing of the antenna structure Fig: 1.*

Figure 6 shows the variation of the fractional bandwidth as a function of value of height parameter and we can see that fractional bandwidth is the highest value at H=6.75mm but the resonant frequency is shift from the desired frequency as shown in figure 7. Therefore, the value of H=7.75mm is chosen. The optimized parameters of the proposed antenna are shown in Table 1.

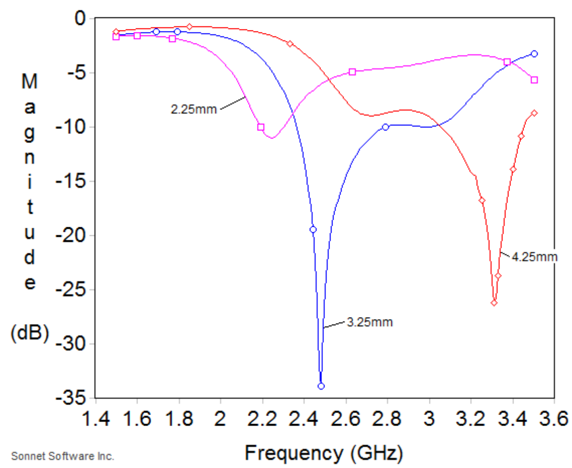

***Fig: 5** Return loss (dB) as a function of frequency with the different value of the feeding width of the PIFA design.*

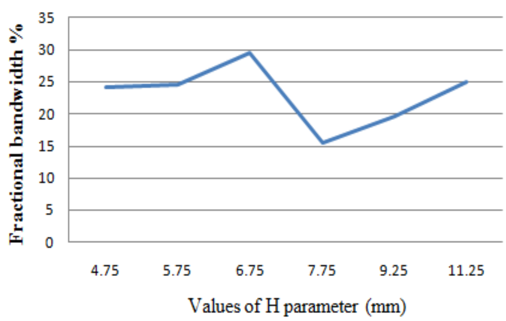

***Fig: 6** Variation of fractional bandwidth (%) as a function of different value of H.*

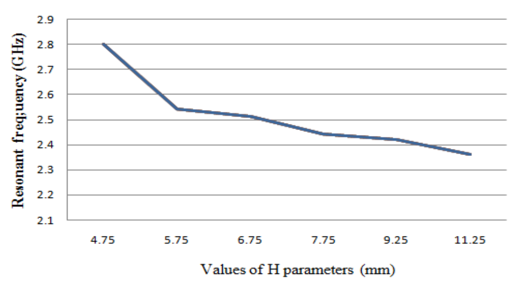

***Fig: 7** Resonant frequency Vs H value*

***Table 1.**Optimized parameters of the proposed antenna*

Antenna Name	Antenna Parameters	Values (mm)	Dimension (mm^2)
PIFA	L1	14	7.75 x 21
	L2	3.75	
	F_w	3.25	
	H	7.75	
	T	1	
	L_g	27.5	
	W_g	21	

III. Simulation Results

The proposed PIFA had been analyzed and simulated by Sonnet Simulator Software. The proposed PIFA has the return loss appreciable than the commonly required 10 dB level. Figure 8 and 9 show the variation of the return loss and Voltage Standing Wave Ratio (VSWR) respectively. This antenna provides the impedance bandwidth of 410MHz (2.37 – 2.78GHz) which fully covers the 2.4GHz band and the peak value of return loss is -33.89dB at the desired band. The value of VSWR of this antenna varies from 1.96 to 1.93 within the operating band and its value is 1.3 at the desired frequency. Figure 10 shows the antenna input impedance variation. From this figure, the input impedance of the proposed antenna is near about 50Ω. Figure 11 shows total radiation pattern of PIFA and which also described the directive gain (dB) of the antenna. In this figure, the total gain value is 5.78dBi at resonant frequency. The average current distribution on PIFA is described in figure 12. The average current density can be read form the axis, the range of current distribution is started from 0 Amp/Meter to 6.3 Amp/Meter at resonant frequency. Table 2 shows the WLAN specifications for IEEE 802.11 models.

***Table 2.** WLAN specifications*

	802.11a
Frequency	2.4GHz
Gain	>1dBi
VSWR	<2
Efficiency	>60%
Bandwidth	>20M
Radiation pattern	Omni-directional

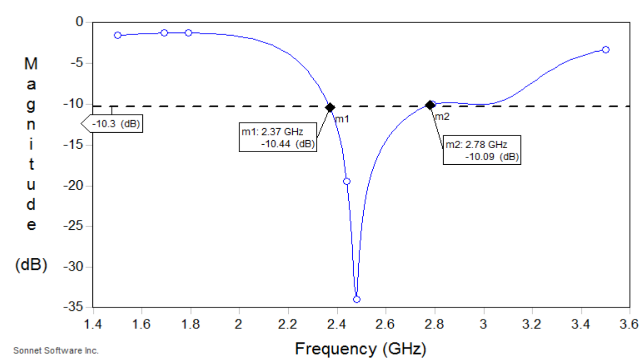

***Fig: 8** Return loss variation of PIFA with frequency*

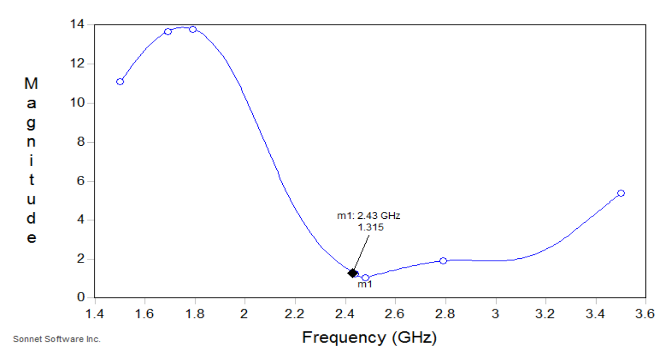

***Fig: 9** Variation of VSWR of PIFA with frequency*

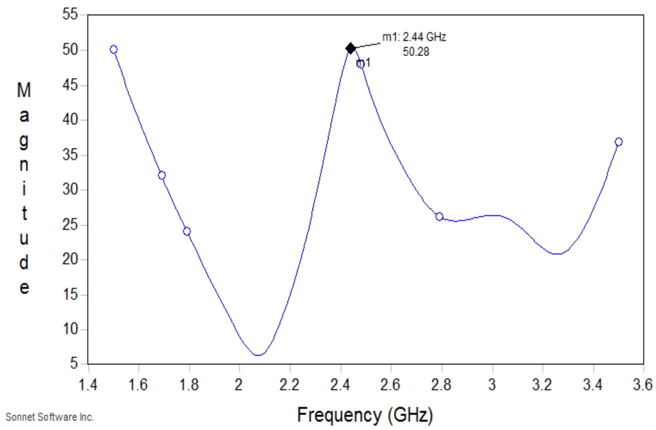

***Fig: 10** Impedance variation of PIFA with frequency*

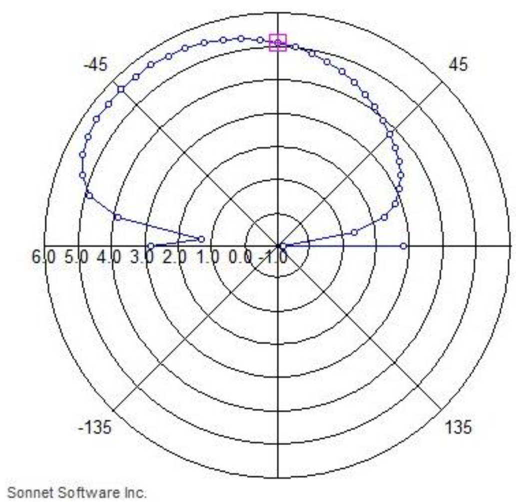

***Fig: 11** Radiation pattern of PIFA*

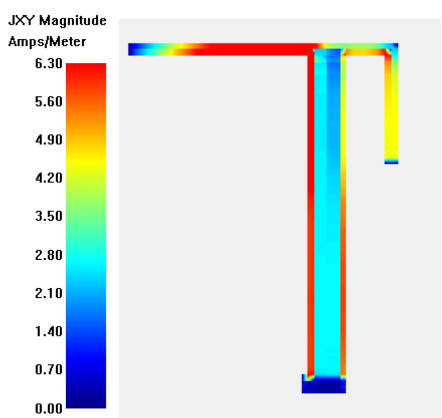

Fig: 12 Current distributions on PIFA

IV. Conclusions
It is shown that the PIFA characteristics are affected by a number of parameters. By increasing the length, width or height of the top plate, the resonant frequency decreases. By increasing the height of the top plate, the fractional impedance bandwidth increases but PIFA needs to be low profile. So, the appropriate height will be chosen. A compact PIFA for WLAN systems has been proposed. This antenna is of compact size with the bandwidth of 410MHz which is enough for desired application. In addition, it also ensures nearly semi-omnidirectional radiation pattern with peak gain of 5.78 dBi across the operating band. From the analysis antenna gain, radiation pattern, return loss and input impedance is suitable for specified application. Due to compactness of the antenna, it is promising to be embedded within the different portable devices employing 2.4 GHz WLAN.

Acknowledgement
The author would like to thank his supervisor Dr. Su Su Yi Mon for her supervisory, suggestions, and advices. And thanks to Dr. Hla Myo Htun, head of department, and all teachers from Department of Electronic Engineering, Mandalay Technological University, for their support and encouragement.

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