

Design and Analysis of Planar Inverted-F Antenna for Wireless Applications

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Abstract

A tri-band planar inverted-F antenna (PIFA) for wireless applications has been presented in this paper. The proposed antenna is compact in size and design on FR4 substrate. The antenna consists of a slotted radiator supported by shorting wall and a small ground plane. Slots in radiating patch have been used to introduce multiband operations into the proposed antenna. The structure is designed and optimized to operate at 2.02GHz, 3.06GHz and 6.1GHz with achievable bandwidths 13.5%, 10% and 16% respectively. These three bands cover the existing wireless communication frequency bands from 1.8- 6.6 GHz. The effects of feed position and shorting wall on return loss, bandwidth, VSWR and gain have been analyzed. Good return loss, antenna gain and radiation pattern characteristics are obtained in the frequency band of interest. Structural dimensions of the proposed antenna are optimized by using HFSS EM solver. Details of the tri-band PIFA characteristics are presented and studied.

Keywords: Planar Inverted-F Antenna (PIFA), Return Loss, Gain, Bandwidth, Effect of Feed Position.

I. INTRODUCTION

In recent years, the demand of compact, smaller than palm size communication devices has increased significantly. Communication system demands for antennas to exhibit some standard properties such as reduced size, moderate gain broadband and multiband operation [1]. With the increasing interest in covering various frequency bands, attention was drawn toward the study of multiband antennas. For multiband antennas, achieving maximum possible frequency bands with suitable return loss and radiation pattern are desirable [2].

Planar Inverted-F Antennas are widely used in a variety of communication systems especially in mobile phone handsets. Also, PIFAs have features such as small size, light weight, low-profile, simple fabrication and relatively low specific absorption rate (SAR) [3, 4]. Due to low absorption of energy in the human body, this antenna provides good efficiency. In recent years, there have been a number of PIFA designs with different configuration to achieve single and multiple operations by using different shapes of slots [5]. Planar inverted-F antennas (PIFAs) can cover two or more standard frequency bands and due to their thin planar structures. Truncated corner technique, meandered strips and meandered shapes have been used to create multiple band operations. Several techniques have been used to improve the bandwidth of PIFA antennas [6]. The introduction of various resonant elements in order to create a multiband PIFA is a very common approach. Another method calls for the addition of parasitic patches with resonant lengths close to the frequency band where the bandwidth improvement is required [7]. The inclusion of slots in the ground plane and in the radiating structure has also been used to enhance the bandwidth.

These antennas are generally designed to cover one or more wireless communications bands such as the Global System for Mobile Communications (GSM900 and 800), Global Positioning System (GPS 1400 and 1575), Personal Communication System (PCS 1800 and 1900), Digital Communication Systems (DCS 1800), Universal Mobile Telecommunications System (UMTS 2000), 3G IMT-2000, 4G LTE(700,1700,2300,2600), Wireless Local Area Networks (WLAN) and Worldwide Interoperability for Microwave Access (WiMAX) etc[8,9].

In this work compact PIFA is proposed and presented for various wireless applications. The effects of different feed positions and shorting wall width are studied. The proposed antenna satisfies the return loss, VSWR and bandwidth for applications within frequency range from 1.8-6.6 GHz. The measured reflection coefficient, radiation pattern, VSWR and gain are characterized.

II. DESIGN AND STRUCTURE

Figure 1 shows the geometry of proposed antenna with detailed dimensions given in Fig 1. The antenna fabricated on FR4 substrate with a dielectric constant $\epsilon_r=4.4$ and a loss tangent of 0.02 and thickness of the substrate $h=1.57\text{mm}$ have been used to

design planar inverted-F antenna. Air is used as dielectric between FR4 substrate and top radiating patch. The dimensional parameters of the proposed antenna are detailed in Table 1. The slots of suitable dimensions are cut in the antenna element to get the required bandwidth. Radiating element slot has been used for producing miniaturization, multi and wide band operation. The proposed antenna has a very small size and is physically thin.

The antenna element is fed by a coaxial probe at the suitable location to get better impedance matching. The thickness of copper used in prototype is 0.16mm. The radiating element of PIFA is grounded with a shorting strip. The proposed antenna is simulated using Ansoft High Frequency Structure Simulator (HFSS), which is full wave electromagnetic simulation software for the microwave and millimeter wave integrated circuits [10]. Ansoft HFSS employs the Finite Element Method (FEM), adaptive meshing, and brilliant graphics to give an unparalleled performance and insight to all of the 3D EM problems. The 3D model of proposed antenna generated in the HFSS is shown in Figure 2. The antenna impedance matching is achieved by controlling the distance between the feed-line and shorting strip. Optimized dimensions of the antenna are given in the Table 1.

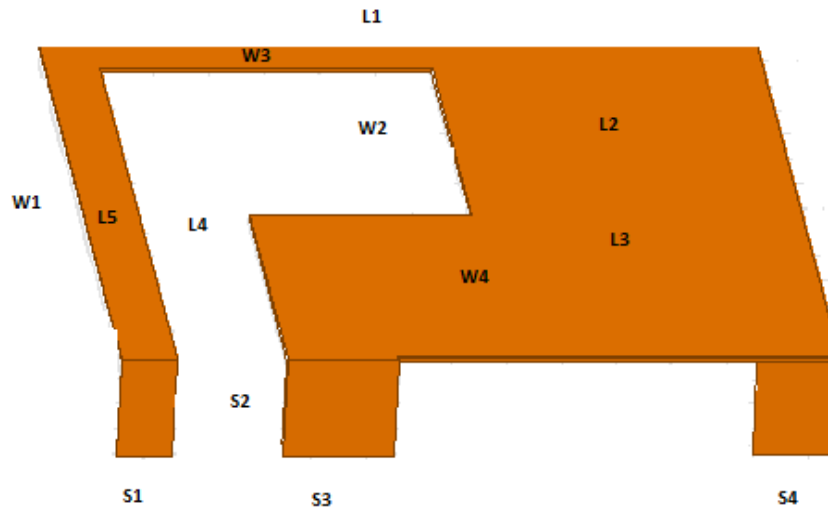


Fig. 1 : Radiating Element of Proposed Antenna

Table - 1
Dimensions of Proposed Antenna

Parameter	Dimension (mm)	Parameter	Dimension(mm)
<i>W</i>	40	<i>L</i>	40
<i>W1</i>	25.6	<i>L1</i>	26
<i>W2</i>	20	<i>L2</i>	12
<i>W3</i>	2	<i>L3</i>	20
<i>W4</i>	11.6	<i>L4</i>	4
<i>S1</i>	2	<i>L5</i>	2
<i>S2</i>	3.57	<i>S4</i>	2
<i>S3</i>	3	Ground Plane	40x40
<i>h 1</i>	1.57	<i>h 2</i>	2

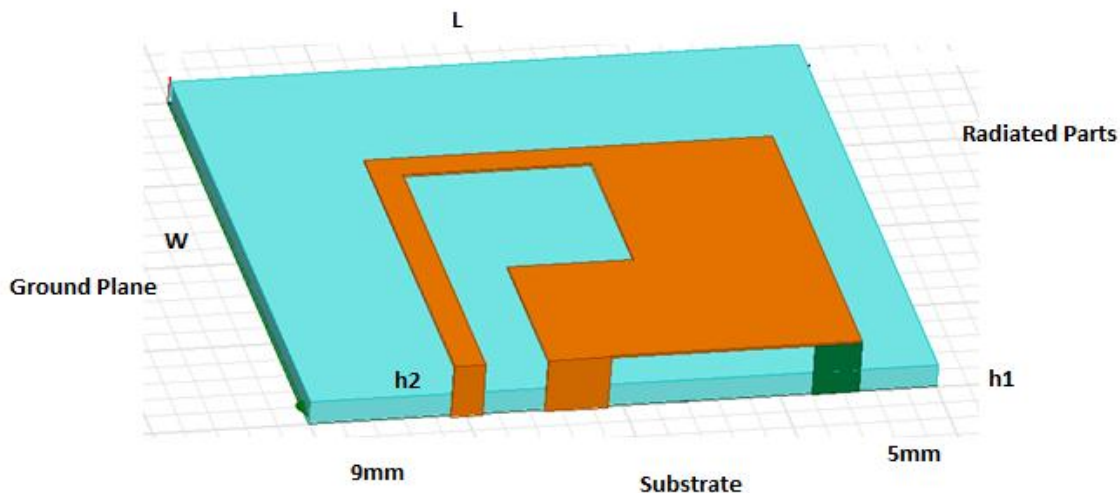


Fig. 2 : 3-D Model of Proposed PIFA Generated In HFSS

III. RESULTS AND DISCUSSIONS

A. Return Loss

The simulated return loss(S_{11}) characteristics of the proposed antenna is shown in Fig.1. From the graph it can be seen that resonant frequencies achieved are 2.02GHz, 3.06GHz and 6.1GHz with return loss of -27.23 dB, -17.40 dB and -27.66 dB. Therefore, the proposed antenna covers the corresponding bandwidths defined by $S_{11} < -6$ dB for the three bands are 13.5% (1.885-2.155GHz) for 2.02GHz, 10% (3.415-3.760GHz) for 3.06GHz and 16% (5.62-6.59GHz) for 6.1GHz. These bandwidths satisfy the requirements for various wireless applications.

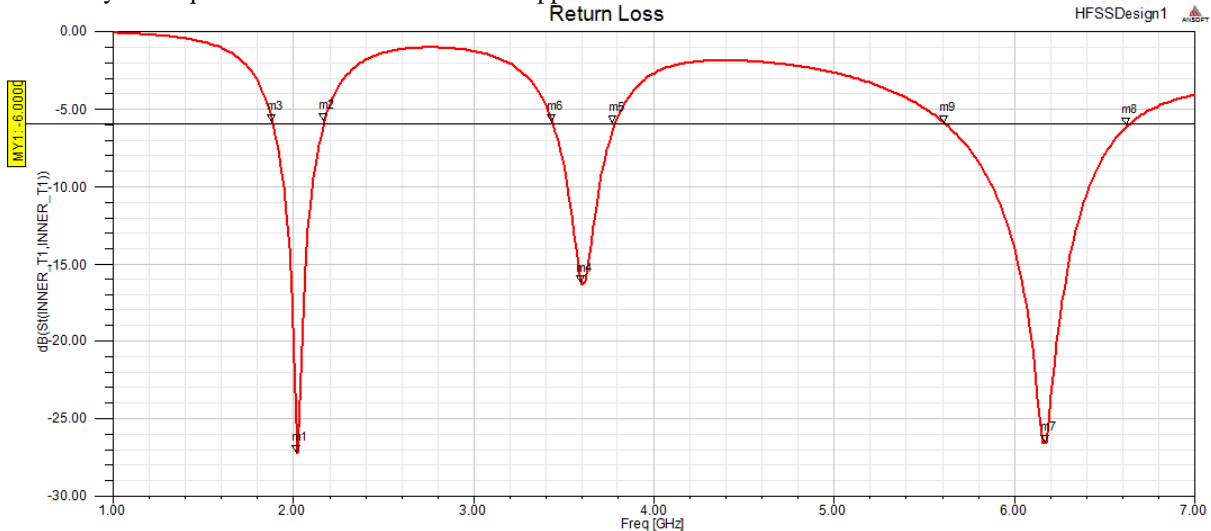


Fig. 3 : Return Loss Graph of Proposed PIFA

B. VSWR

Voltage Standing Wave Ratio (VSWR) is a ratio of peak voltage on the minimum amplitude of voltage of standing wave . The VSWR is always a real and positive number for antennas. The smaller the VSWR is, the better the antenna is matched to the transmission line and the more power is delivered to the antenna. It is illustrated in Fig. 4 that at 2.02 GHz VSWR is 0.8 dB at 3.06GHz VSWR is 2.0 dB , at 6.1GHz VSWR is 0.7 dB Also it is observed from the results that at these resonant frequencies the Voltage Standing Wave Ratio is below 2 dB which is desirable for most of the wireless applications.

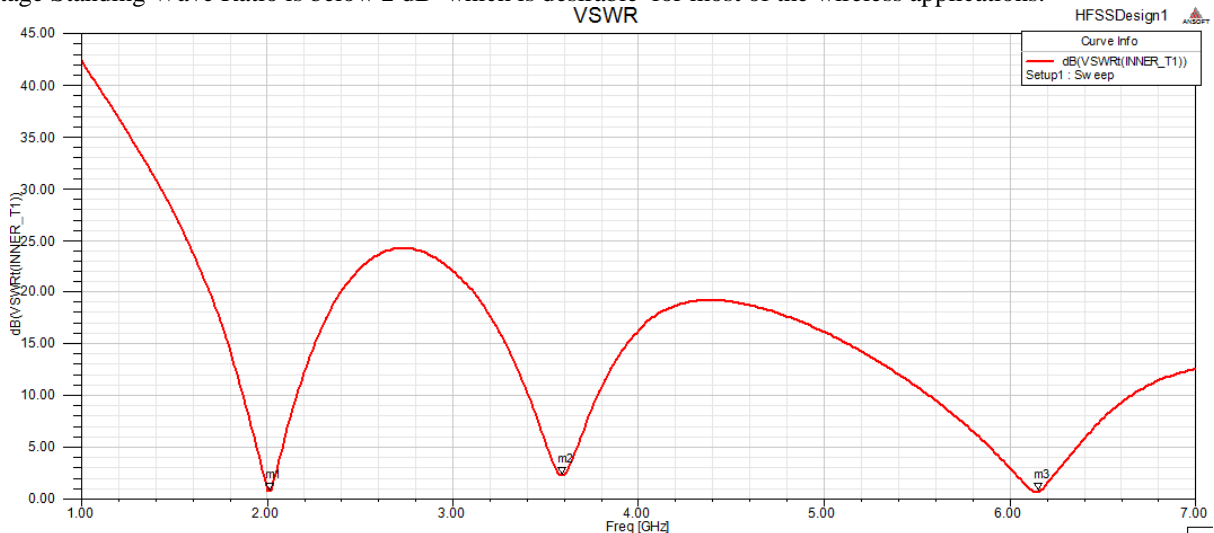


Fig. 4 : VSWR Plot of The Proposed Antenna

C. Radiation Pattern

The radiation pattern of the PIFA is the relative distribution of radiated power as a function of direction in space. In the usual case the radiation pattern is determined in the far-field region and is represented as a function of directional coordinates. It can be seen from the plot of Fig. 5, that the antenna is a good radiator with almost omnidirectional radiation which supports multiple standards.

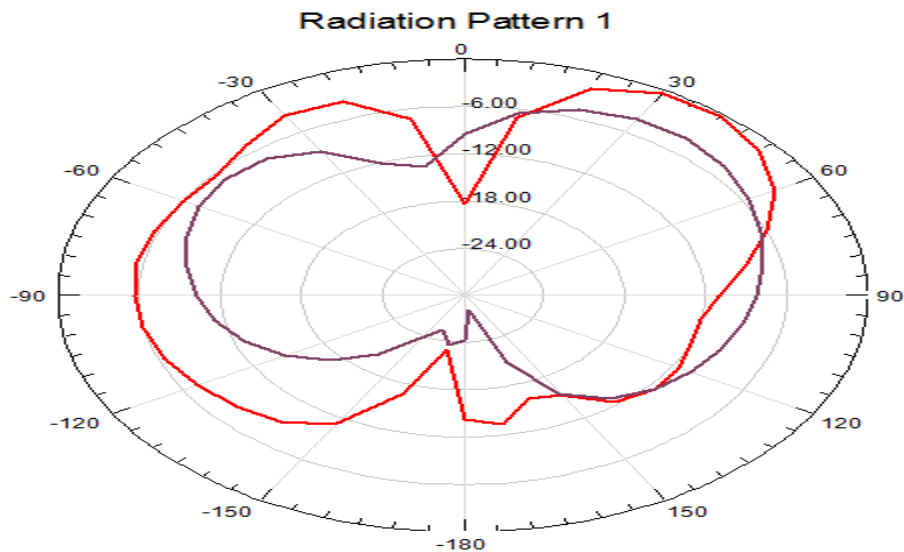


Fig. 5 : Radiation Pattern of Proposed PIFA At Phi 0 And 90 Degree

D. Gain

The gain and efficiency are the two important parameters of the antenna. The overall gain of the antenna obtained after simulating the PIFA structure is shown in Fig. 6. A peak gain of 3.36 dB has been achieved. This value of gain achieved by the proposed structure is moderate value and considered to be good for the overall performance of the antenna.

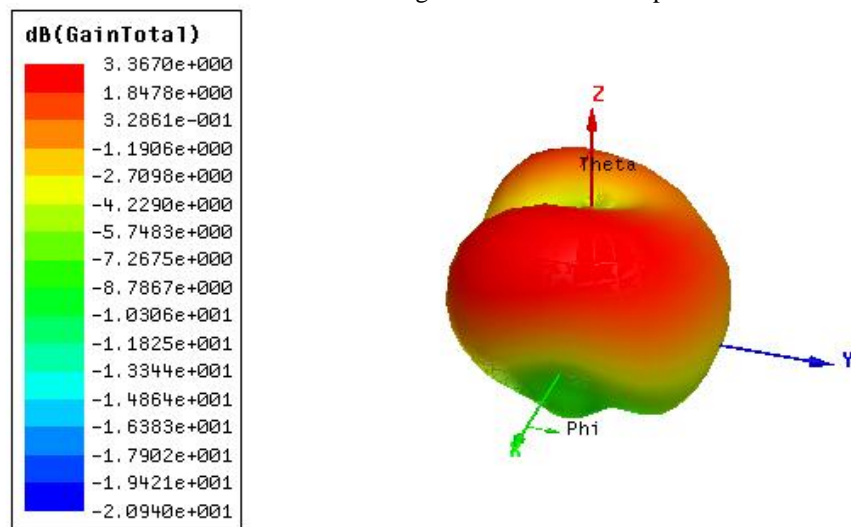


Fig. 6 : 3-D Polar Plot Showing Gain

IV. EFFECT OF FEED POSITION ON THE PROPOSED PIFA PERFORMANCE

The feeding point position is calculated from the rear edge of the patch. The different effects of feed by varying the position on resonating frequency, return loss, VSWR, Gain and bandwidth are shown in Table 2. From the obtained results, it has been observed that feed position at (35,25) is the most suitable option for the proposed PIFA structure.

Table 2
Effects of Feed Position On Different Parameters of PIFA

Feed Position (x,y) in mm	Resonating Frequency (GHz)	Return loss (dB)	VSWR (dB)	Bandwidth (%)	Gain (dB)
35,23	2	-33.45	0.3	13	3.41
	3.58	-14.37	3.3	8.9	
	6.22	-23.79	1.1	19.7	
35,24	2.02	-30.65	0.5	13.3	3.28
	3.5	-15.56	2.9	9.1	
	6.17	-23.12	1.3	18.4	

35,25	2.02	-27.23	3.2	15	3.37
	3.06	-17.40	0.7	11.3	
	6.1	-27.66	1.02	19.6	
34,25	2.03	-18.98	1.9	14.7	2.76
	3.61	-20.14	1.7	10.2	
	6.19	-25.33	0.9	17.2	
33,25	2.06	-14.68	3.2	15	3.37
	3.61	-26.91	0.7	11.3	
	6.25	-24.43	1	19.5	
32,25	2.08	-12.44	4.2	15.8	4.51
	3.65	-27.72	0.6	12	
	6.28	-31.12	0.5	21.3	

V. EFFECT OF SHORTING STRIP WIDTH ON PROPOSED PIFA PERFORMANCE

In order to analyse the effect of shorting strip on the performance of proposed antenna, dimension of strip width (S4) has been varied from 0.5 to 5 mm. The presented results given in Table 3 has revealed that strip width of 2 mm can be consider as the suitable option to get the required results in terms of return loss, VSWR, bandwidth and gain.

Table 3
Effects of Shorting Strip Width On Different Parameters of PIFA

Width of Shoting Strip (mm)	Resonating Frequency (GHz)	Return Loss (dB)	VSWR (dB)	Bandwidth (%)	Gain (dB)
0.5	1.9	-14.95	3.1	16.4	3.40
	3.5	-21.91	1.3	11.4	
	6.03	-27.68	0.7	20.3	
1	1.96	-15.94	2.7	15.8	3.41
	3.57	-20.09	1.6	11.2	
	6.06	-26.54	0.8	19.3	
2	2	-20.29	1.6	14.5	3.21
	3.57	-18.52	2	10.3	
	6.12	-26	0.8	18.1	
4	2.03	-36.86	0.2	11.8	3.17
	3.61	-14.37	3.3	8.5	
	6.17	-30.54	0.6	16.2	
5	2.06	-25.4	0.9	11.6	3.50
	3.63	-12.86	4	8.2	
	6.21	-32.3	0.4	14.4	

VI. CONCLUSION

In this paper a multiband Planar Inverted-F Antenna, has been presented which covers the frequencies between 1.8-6.6GHz. The proposed antenna has a simple configuration and is simply printed on FR4 substrate. Slots in the radiating patch, exact feed location and shorting strip width have been employed and their effects on the performance of the antenna has been analyzed. It has been found that making slots in the radiating patch and slits in the ground plane provides a simple multiband PIFA with enhanced bandwidth. The proposed antenna can covers UMTS, DCS, PCS, GPS, 3G, 4G, WiMAX (3571-3900MHz) and an additional frequency bands, and provides good return loss, VSWR and radiation patterns.

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