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Design and Simulation of Planar Inverted F Antenna for ISM Band Applications using HFSS

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Abstract — This paper describes the design and simulation of a probe fed PLANAR INVERTED F ANTENNA (PIFA), operating at 2.4 GHz ISM band frequency; using HFSS simulator. Parameters like height of the patch from the ground, shorting plate dimensions and feed position are optimized to obtain a high gain PIFA. Bandwidth of the designed antenna is 281 MHz and gain is 3.8219 dB.

Index Terms—Antenna, HFSS, ISM band, PIFA, parametric analysis, simulation, shorting plate at feed

1 Introduction

THE Planar Inverted F Antenna (PIFA) is increasingly used in the mobile market because it is a low profile antenna with omnidirectional pattern. The antenna is resonant at a quarter-wavelength (thus reducing the required space needed on the device) [1]. In general PIFA consists of a large ground plane, a top radiating patch, feed wire attached between ground plane and top radiating patch through the substrate, and a shorting wire or plate. The antenna is fed at the base of the feed wire at the point where wire connects to ground plane. In addition the shorting plate provides a good impedance matching with the top radiating patch. The resulting antenna is more compact than conventional half-wavelength probe fed patch antenna [2]-[3].

The industrial, scientific, and medical radio band (ISM band) refers to a group of bands or parts of the radio spectrum that are internationally reserved for the use of radio frequency (RF) energy intended for scientific, medical and industrial requirements. ISM bands are generally open frequency bands, which vary according to different regions and permits. The 2.4 GHz ISM band is commonly accepted band for worldwide operations [4]. The use of 2.4 GHz industrial, scientific and medical (ISM) band is becoming an important means of wireless communication. Wireless local area networks (WLAN), wireless internet at any access-point equipped building, Bluetooth and Zigbee wireless networks all utilize the 2.4 GHz ISM Band. Therefore, the development of appropriate antenna design is essential.

For these kinds of applications the designed antenna should have a smaller size. Hence PIFA is a good option for these kinds of applications. Various parameters like dimension of the top radiating patch, feed point position, height of the radiating patch, shorting plate width and position, effect antenna characteristics [5]. By optimizing these parameters a PIFA is designed. Bandwidth of the designe antenna is 281 MHz and gain is 3.8219 dB.

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2 Design Methodology

2.1 Description of Antenna

The resonant frequency is not very sensitive to the dimension of the ground plane; this could be due to the fact that the antenna dimension is the dominant factor for radiation [6]. As the designed antenna resonates at ISM band and is to be used in mobile devices hence it should be compact. Length and width of the ground plane are taken as L_g= 100mm and W_g= 60mm. length of the radiating patch is denoted by L_P and width is W_P fig (1). The patch is fed by a coax which has the resistance of 50Ω. Inner wire of the coax is extended beyond the ground through the substrate to patch. Shorting plate has width W_s. Height of the patch from the

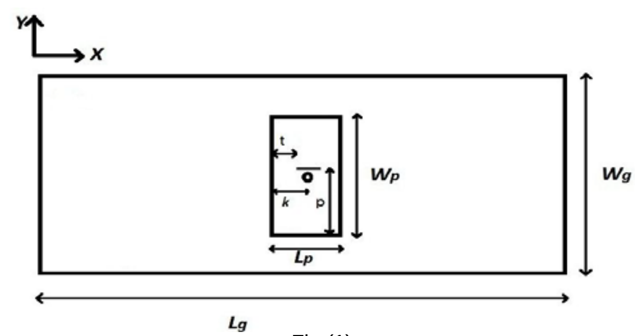


Fig (1)

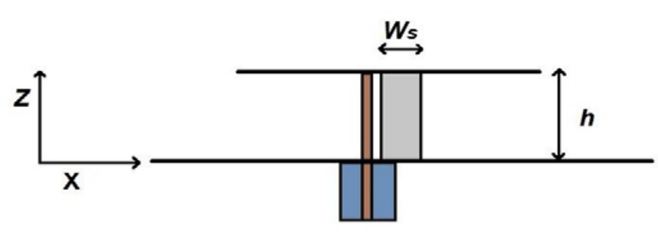


Fig (2)

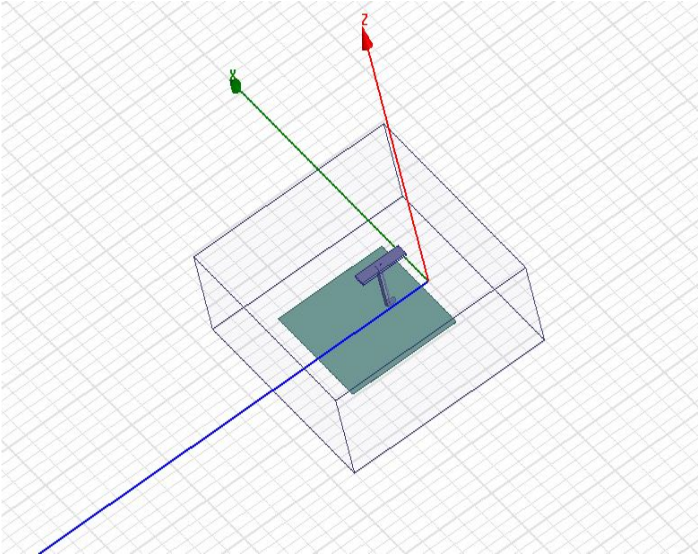


Fig (3)

ground is given by *h*. Space between patch and ground is mostly air except a thin region (0.8mm) composed of FR_epoxy ($\mathcal{E}_r$ = 4.4); under the patch. To shrink the size of antenna, high constant dielectric substrate material can be used [5]. But this weakens the performance of antenna, because it gathers electromagnetic fields and therefore does not radiate as good as the air insulated PIFA [7]. Also part of the feed power goes into dielectric losses of the substrate material [7].

2.2 Mathematical analysis of resonant frequency

The generalized formula for the calculation of resonant frequency is given by [2]:

$$fr = c \div (4 \times (Lp + Wp - Ws)) \qquad (1)$$

Here C = $C_0/\sqrt{\mathcal{E}_r}$, where C_0= 3×10^8 m/sec. For our case $\mathcal{E}_r$ = 1, as we have used air dielectric. According to this equation resonant frequency depends upon patch dimension and shorting plate width. For the designed PIFAlength of the patch L_p= 25mm, width of patch W_p= 10mm, and shorting plate width W_s = 3.8mm, which gives *fr* = 2.403 GHz, which is the desired frequency. Shorting plate width is further optimized for better results.

2.3 Software used for Simulation

HFSS (High Frequency structural simulator) is used for the analysis of antenna. HFSS is a commercial finite element method solver for electromagnetic structure [8]. It is one of the several commercial tools used for antenna design of complex RF electronic circuit elements including filters, transmission-lines, and packaging [8]. Ansoft HFSS has evolved over a period of years with input from many users and industries. In industry, Ansoft HFSS is the tool of choice for High productivity research, development, and virtual prototyping. It integrates simulation, visualization, solid modeling, and automation in an easy to learn environment where solutions to your 3D EM problems are quickly and accurate obtained. Ansoft HFSS employs the Finite Element Method (FEM), adaptive meshing, and brilliant graphics to give you unparalleled performance and insight to all of your 3D EM problems. Ansoft HFSS can be used to calculate parameters such as S-Parameters, Resonant Frequency, and Fields [9].

2.4 Effect of Height of the patch from the ground plane

Antenna height is the distance of the patch from the ground. According to [6] increase in the height of antenna decreases the resonant frequency. Hence height of the antenna is varied from h= 12.4 mm to h= 17.4 mm. Simulated results have been shown in fig (4). It is clear from the fig (4) that resonant frequency decreases as height of the antenna is increased. Hence for h= 15.4mm we get 2.4 GHz resonant frequency. Return loss S (1, 1) is about -16.39 dB; which is acceptable.

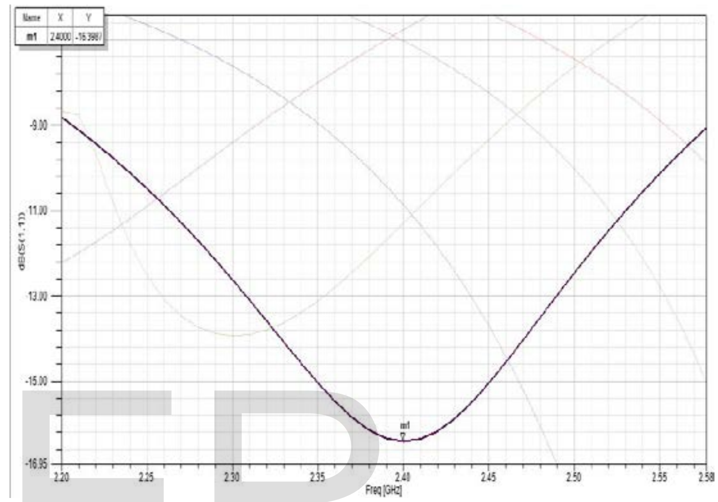


Fig (4)

2.5 Effect of Feed Position

Position of feed effects resonance frequency and bandwidth of the antenna [7]. Feed is placed at the centre of the patch and varied along the x-axis from k = 1mm to k = 9mm. Fig (5) shows that for k = 5mm, we get resonant frequency = 2.44 GHz and S_{11} = -27.353

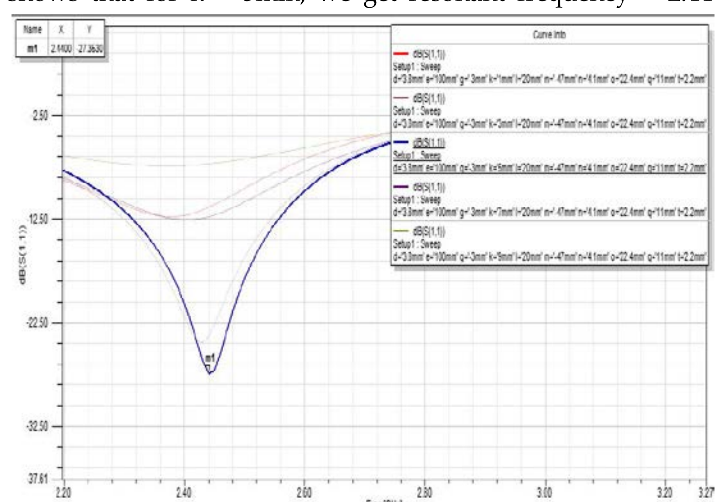


Fig (5)

2.6 Position of shorting plate

In this model shorting plate is placed at the feed to the patch. It gives very interesting result. In this case it may be assume that shorting plate would zero out any power delivered to the antenna [1]. However, because patches are high frequency devices (typically used at frequency more than 1 GHz), the shorting plate actually produces a parallel inductance to the circuit of the antenna impedance [1]. The antenna impedance is given by Z_A, and the shorting plate introduces a reactance equal to jX [1]. This parallel inductance shifts the resonant frequency of the antenna. In particular, the admittances of the two parallel components would be added [1]. Hence 1/(jx) would be added to its admittance [1]. Shorting plate position is optimized for the best results. Position of shorting plate along y-axis is varied from p = 13.5mm to 15.5 mm. from fig (7) it can be shown that p =14.9mmgives the best result. In the

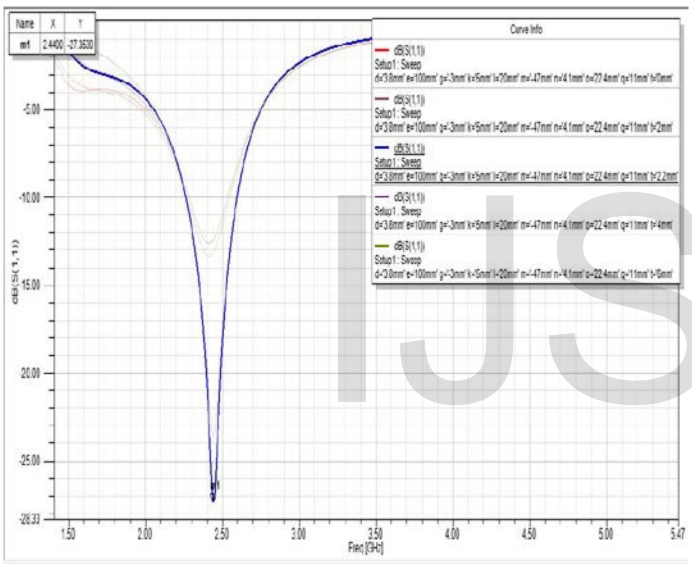
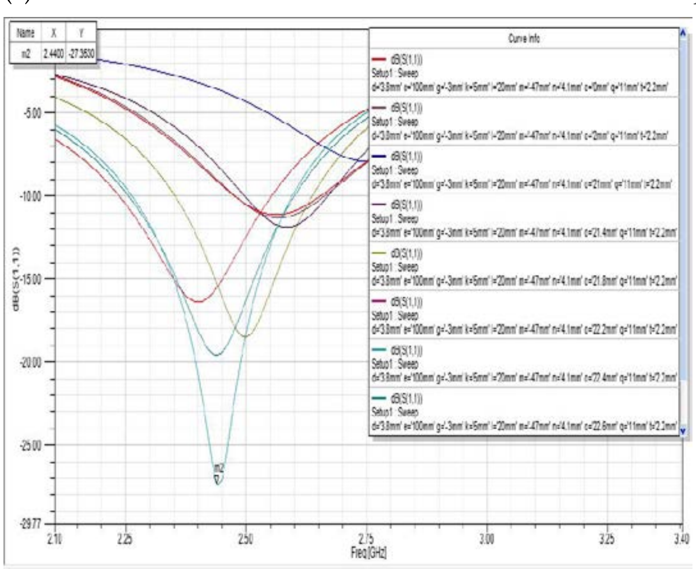


Fig (6)

same way, position along x-axis is varied from t = 1 to t = 6 fig (6). Best result is obtained for t = 2.2mm.For these values of p



and t, the S_{11} = -27.353 dB. Fig (7)

2.7 Width of the Shorting plate'Ws'

Width of the shorting plate affects the resonant frequency [6]. To see the effect of W_s, it is varied from W_s = 3.7mm to W_s= 4.7 mm. It is clear from the fig (8) that, W_s= 4.5mm gives the

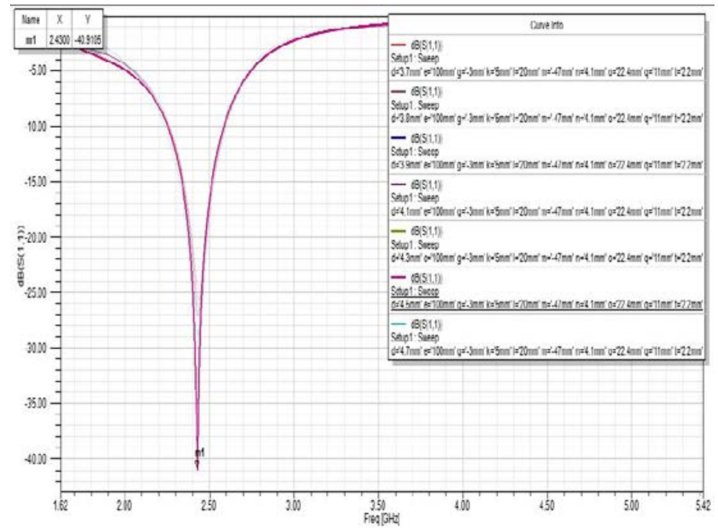


Fig (8)

best result. S_{11} for this value is -40.91 dB at 2.43 GHz frequency.

3 Designed Antenna Parameters

All optimized dimensions are given in the table (1).

Table (1)

Antenna parameters	Value (mm)
Patch length, L_p	10
Patch width, W_p	25
Ground length, L_g	100
Ground width, W_g	60
Patch height, h	15.4
Feed position along X, k	5
Feed position along X, l	12.5
Shorting plate width, W_s	4.5
Shorting plate position, p	14.9

3.1 Antenna Return Loss and Bandwidth

Fig (9) shows the return loss of the designed antenna
The central frequency for the designed antenna is 2.43 GHz which is very close to the 2.4 GHz ISM band frequency. At this frequency antenna returnloss is -40.9105 dB. Bandwidth for the designed antenna is 281 MHz which is calculated for return loss ≤ -10 dB.

3.2 Gain and 3D Polar Plot of Antenna

Gain of the antenna represents the amount of power transmitted in the direction of peak radiation to that of an isotropic source [10]. The designed antenna has the gain G = 3.8219 dB at 2.43 GHz fig (10).

3.3 Radiation Pattern of the antenna

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.

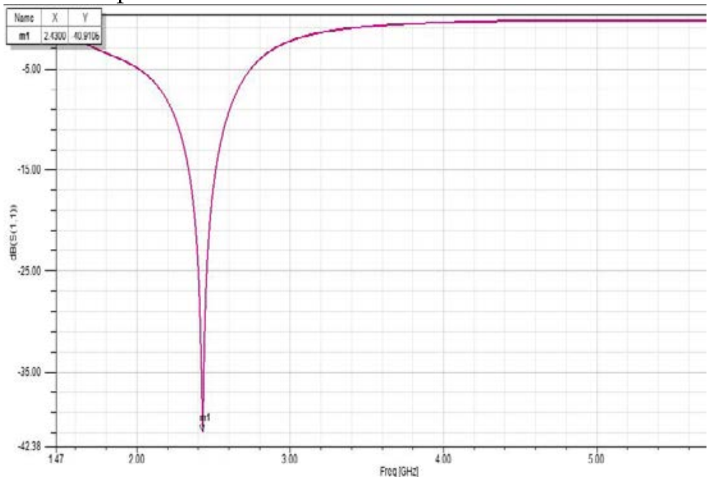


Fig (9)

Radiation properties include power flux density, field strength, phase, and polarization [11]. The far field radiation pattern at 2.43 GHz frequency is shown for Phi =0 in fig (11).

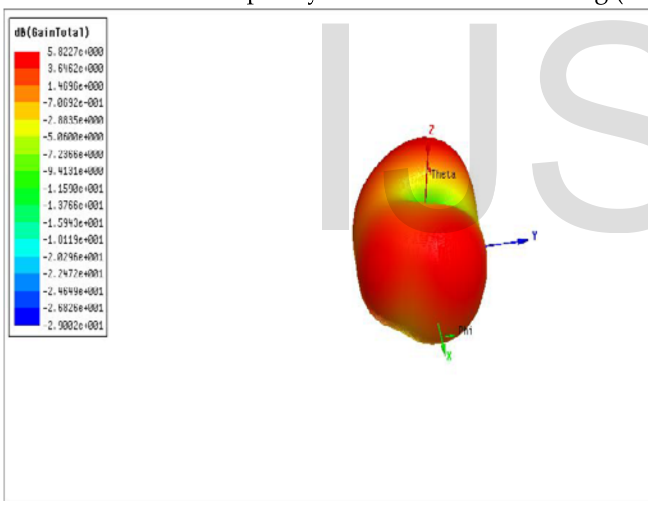


Fig (10)

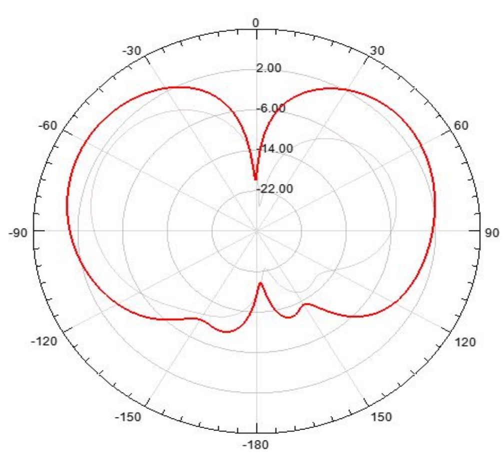


Fig (11)

Table (2)

Inputs

Setup Name:	Infinite Sphere1
Solution:	Sweep
Array Setup:	None
Intrinsic Variation:	Freq='2.43GHz'
Design Variation:	a='0' b='7.5mm' c='25mm' d=

OK | Export | Export Fields

Antenna Parameters:

Quantity	Value	Units
Max U	0.3041	W/sr
Peak Directivity	1.6759	
Peak Gain	3.8219	
Peak Realized Gain	3.8215	
Radiated Power	2.2803	W
Accepted Power	0.99992	W
Incident Power	1	W
Radiation Efficiency	2.2805	
Front to Back Ratio	7.873	
Decay Factor	0	

Maximum Field Data:

rE Field	Value	Units	At Phi	At Thet
Total	15.142	V	160deg	59deg
X	9.5579	V	170deg	40deg
Y	6.9841	V	300deg	44deg
Z	13.783	V	160deg	71deg

4 Conclusion

A Planar Inverted F Antenna is designed for 2.4 GHz ISM band. Different designing parameters like height of the antenna, feed position, shorting plate dimensions and positions are varied and optimized for the best results in the ISM band.It can be seen that each antenna parameter affects the antenna characteristic results, it means each parameter has a significant effect on antenna characteristics. Effect of placing shorting plate at feed is discussed due to which some extra impedance is added to the circuit which affects the resonant frequency. The designed antenna has an omnidirectional pattern. It provides gain of 3.8219 dB and radiation efficiency of 2.2805. It has the bandwidth of 281 MHz. It is a very small size antenna which can easily be mounted on any mobile device.

Table (2) shows the characteristic results of the designed antenna and various antenna parameters.

References

[1] www.antenna-theory.com/antennas/patches/pifa.php

[2] Abdelhakim Elouadih, Ahmed Oulad-Said, Moha Mrabet Hassani, "Design and Simulation of a miniaturized PIFA antenna for PCS band," *Wireless Engineering and Technology*, 2013, 4, 105-111 Http://dx.doi.org/10.4236/wet.2013.42016

[3] K. L. Wong, "Introduction and Overview," In: K. L. Wong, Ed., Planar

ISSN 2229-5518
Antennas for Wireless Communications', John Willy and Sons, Hoboken, 2003, p. 1.

[4] tecnopedia.com/definition/27785/industrial/scientific-and-medical-radio-band-ism-band

[5] K. L. Virga and Y. Rahmat-samii, "Low-Profile En-hanced Bandwith PIFA for Wireless Communications Packaging," IEEE Transactions on Microwave Theory and Techniques, Vol. 45, No. 10, 1997, pp. 1879-1888. doi:10.1109/22.641786

[6] Hassan Tariq Chattha, Yi Huang, *Senior Member,"An empirical equation for predicting the resonant frequency of PIFA," IEEE*, Xu Zhu, and Yang IEEE antenna and propagation letters VOL. 8, 2009

[7] HALA ELSADEK ,"Microstrip antennas for mobile wireless communication system," electronics research institute microstrip department, Cairo Egypt

[8] Ansoft Corporation, "HFSS 10.0 User's Guide," Ansoft Corporation, Pittsburg, 2005.

[9] Dr. Otman El Mrabet, "High Frequency Structure Simulator (HFSS) Tutorial," IETR, UMR CNRS 6164, INSA, 20 avenue Butte des Coësmes 35043 Rennes, FRANCE

[10] Mr. Nawale Sagar. S, Dr. Kakade. A. B, International Journal of Engineering Research & Technology (IJERT) Vol. 2 Issue 8, and August – 2013 ISSN: 2278-0181

[11] Iulian Rosu, "PIFA – Planar Inverted F Antenna," *YO3DAC / VA3IUL http://www.qsl.net/va3iul*