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Performance Analysis of Patch and PIFA Antenna for WCS and SDR Applications

Anjali[1], Amrit Kaur[2]

M.Tech Student, ECE Department, BBSBEC, Fatehgarh Sahib, India [1]

Asst. Professor, ECE Department, BBSBEC, Fatehgarh Sahib, India [2]

Abstract: The performance analysis of Patch antenna and PIFA (Planar Inverted F Antenna) for operating frequency of 2.4 GHz is presented in this paper. The proposed antenna structure covers WCS (Wireless Communications Service- 2.305-2.32 GHz and 2.345-2.36 GHz) and SDR (Satellite Digital Radio- 2.32-2.325 GHz) bands. The design steps and the detailed dimensions for the antenna structures are discussed. The results for return loss and VSWR are simulated with the help of Ansoft HFSS v13.0. The comparison of Patch antenna and PIFA antenna in terms of return loss is also discussed.

Keywords: HFSS, PIFA, SDR, WCS.

I. INTRODUCTION

Antenna is an electrical device used for converting the electrical current into electromagnetic radiation and vice-versa. It is an important element for any wireless system. The performance of the wireless system is highly dependent on the design of antenna and its implementation. Now-a-days, the technological advancement in the compact wireless devices like mobile phones increases the demand of internal antennas. The Microstrip Patch antenna and PIFA antenna are most widely used internal antennas for the compact hand-held devices. The antennas must be small in size to construct into the device and have good performance in terms of bandwidth, return loss, gain etc. [1]. Microstrip Patch and PIFA antennas are small in size, low profile and easy to fabricate using the PCB (Printed Circuit Board) technology [2]. Also, PIFA seemed as one of the most pledge candidate in the categories of low profile antennas [3]. But the narrow bandwidth of these antennas is one of the limitations [4]. Microstrip Patch antenna consists of a radiating patch built on the ground plane with the substrate of dielectric material sandwiched between them [5]. On the other hand, PIFA is similar to patch antenna but has a shorting element to decrease the physical length of antenna and has the radiating patch placed at some height from ground and substrate [6-7]. It is considered as a variant of monopole antenna in which top section is folded down to become parallel to the ground plane [8].

In this paper, Patch and PIFA antennas with resonant frequencies of 2.37 GHz and 2.45 GHz which can cover WCS and SDR bands with achievable bandwidth of 2.19% and 16.68% respectively is presented. The simulated results for return loss and VSWR have been discussed. The comparison of the return loss values for both antennas has also been discussed.

II. DESIGN CONSIDERATIONS FOR PATCH AND PIFA ANTENNA

A. Design Considerations for Patch Antenna

The design steps for Patch antenna are illustrated with the help of flowchart as given in Fig. 1. First, the resonant frequency of antenna (f_r), type of substrate and its dielectric constant (ε_r) and height (h) is chosen and then the calculations of width, length and all the other dimensions for antenna has been prepared with the help of some standard equations as described in [9-10].

B. Design Considerations for PIFA antenna

The design steps for PIFA antenna as shown in Fig. 2, are illustrated by the general equations (1) and (2) as given below:

$$L_1 + L_2 - W = \frac{\lambda}{4} \qquad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

and resonant frequency,

$$f_0 = \frac{c}{4(L_1 + L_2 - W)} \qquad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

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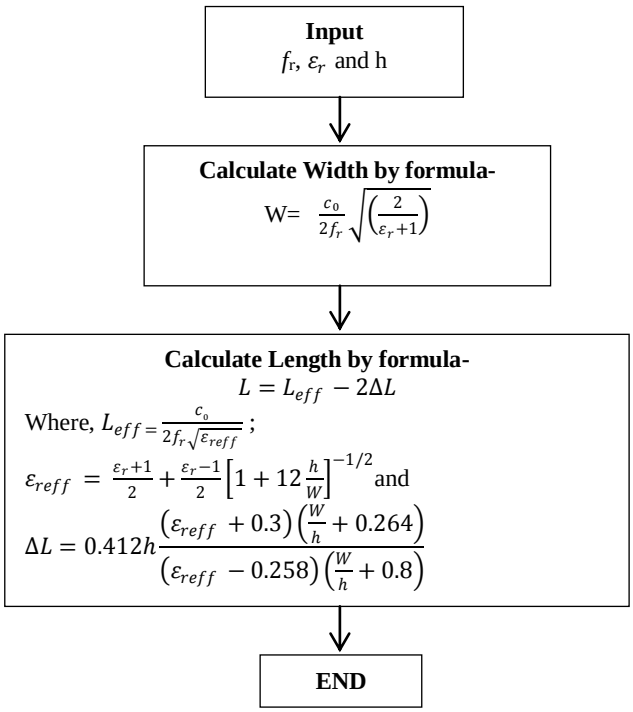

Fig. 1 Flowchart based on design of rectangular patch antenna

Where, c_0 is the speed of light; L_{eff} is the effective length of Patch; ε_{reff} is the effective dielectric constant and ΔL is the extended length of Patch respectively.

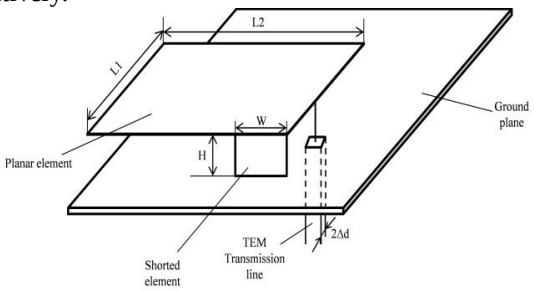

Fig. 2 Structure of PIFA [2]

Here, L_1, L_2 and W is the Length of radiating patch, Width of radiating patch and Width of the Shorting plate respectively, f_0 and c is the resonant frequency and speed of light respectively.

III.DESIGN OF PROPOSED ANTENNAS

Fig. 3 shows the structure for patch antenna in HFSS.

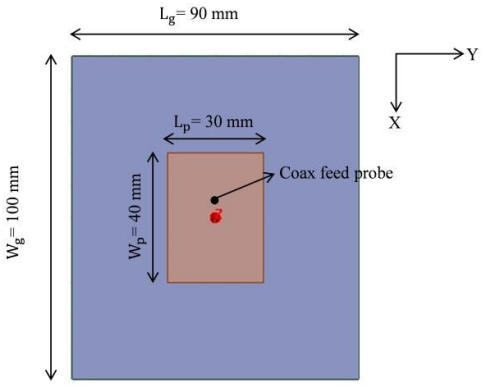

Fig. 3 Structure of Patch antenna in HFSS

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TABLE I shows the detailed dimensions of proposed patch antenna structure. The structure consists of a rectangular patch of dimension $L_p \times W_p$, a substrate and ground plane of dimension $L_g \times W_g$. The substrate of material Rogers RT/duroid 5880 of dielectric constant = 2.2 and height = 3.2 mm is used. The design steps mentioned in previous section were followed to obtain the dimensions for this structure and optimized for appropriate results.

TABLE I Dimensions for Proposed Patch Antenna

Dimension	**Value (mm)**		
L_g	100		
W_g	90		
L_p	40		
W_p	30		
Substrate details- Rogers RT/duroid 5880			
Length = 100 mm Width = 90 mm	Height (h) = 3.2 mm	Dielectric constant (ε_r) = 2.2	Dielectric loss tangent (δ) = 0.0009
Feed type- Coaxial probe			

Fig. 4 shows the structure of PIFA antenna with dimensions. Fig. 5 shows the side view of proposed PIFA antenna in HFSS. The proposed design of PIFA antenna consists of a radiating patch of dimension $L_p \times W_p$, a ground plane and substrate of dimension $L_g \times W_g$, a shorting plate of dimension $L_s \times W_s$, and a coaxial feed. The design for this structure is based on FR4_epoxy substrate material with dielectric constant of 4.4 and thickness of 7 mm. The height of top radiating patch from ground plane is H = 15.4 mm. The position of the coaxial probe is taken as (-5, 0, 0). The TABLE II shows the dimensions for the proposed PIFA antenna.

TABLE III Dimensions for Proposed PIFA Antenna

Dimension	**Value (mm)**		
L_g	60		
W_g	100		
L_p	10		
W_p	25		
Substrate details- FR4 epoxy			
Length = 60 mm Width = 100 mm	Height (h) = 7 mm	Dielectric constant (ε_r) = 4.4	Dielectric loss tangent (δ) = 0.02
Feed type- Coaxial probe			
Shorting plate details-			
Length (L_s = H)	15.4 mm	Width (W_s)	4.5 mm

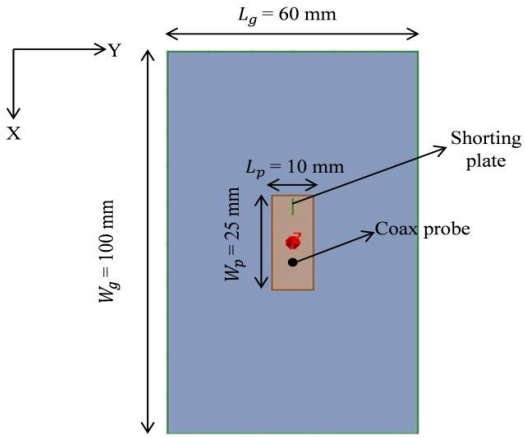

Fig. 4 Structure of PIFA antenna in HFSS

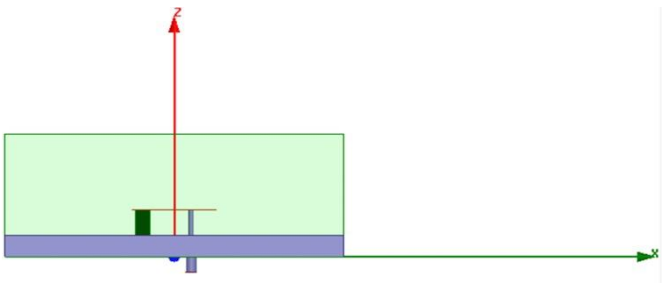

Fig. 5 Side view of PIFA antenna in HFSS

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IV. RESULTS AND DISCUSSIONS

A. Return Loss

The performance parameters of Proposed Patch and PIFA antenna have been simulated in Ansoft HFSS v13.0. In Fig. 6 and Fig. 7, the frequency response of simulated S11 parameters has been shown. The return loss in dB of the proposed Patch and PIFA antenna is obtained as -30.6579 dB and -41.0466 dB at the resonant frequency of 2.37 GHz and 2.45 GHz respectively. The impedance bandwidth of the Patch and PIFA antenna at -10 dB return loss is 51.9 MHz (2.3465-2.3984 GHz) and 412.6 MHz (2.2669-2.6795 GHz) respectively, which covers the WCS and SDR bands.

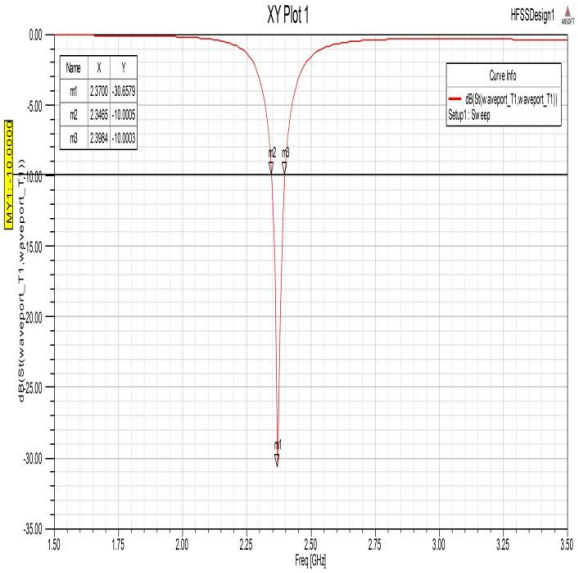

Fig. 6 S11 parameter or return loss of proposed Patch antenna

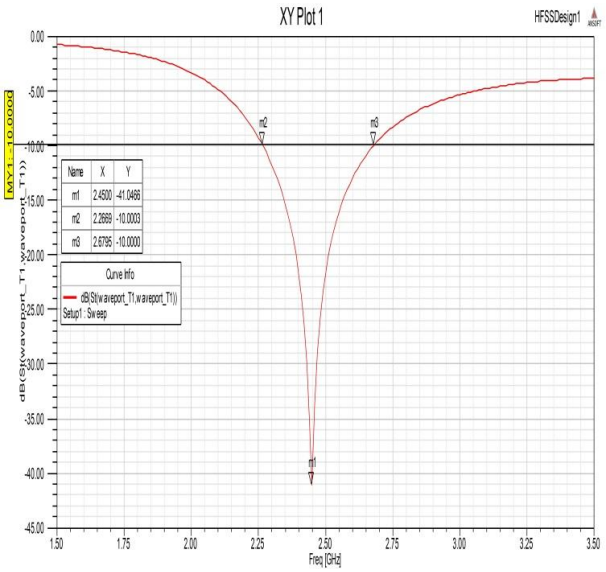

Fig. 7 S11 parameter or return loss of proposed PIFA antenna

B. VSWR (Votage Standing Wave Ratio)

The simulated results for VSWR of Patch and PIFA antenna are shown in Fig.8 and Fig. 9. The value of VSWR for Patch antenna at resonant frequency of 2.37 GHz is obtained as 0.5094 and for PIFA antenna, it is obtained as 0.1540 at the resonant frequency of 2.45 GHz.

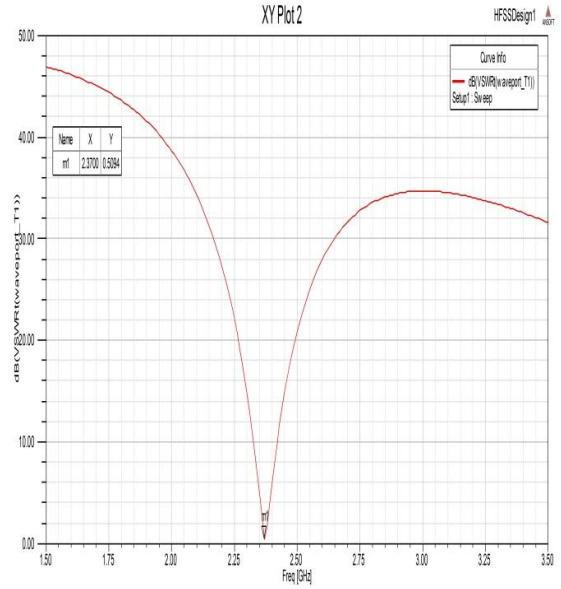

Fig. 8 VSWR of proposed Patch antenna

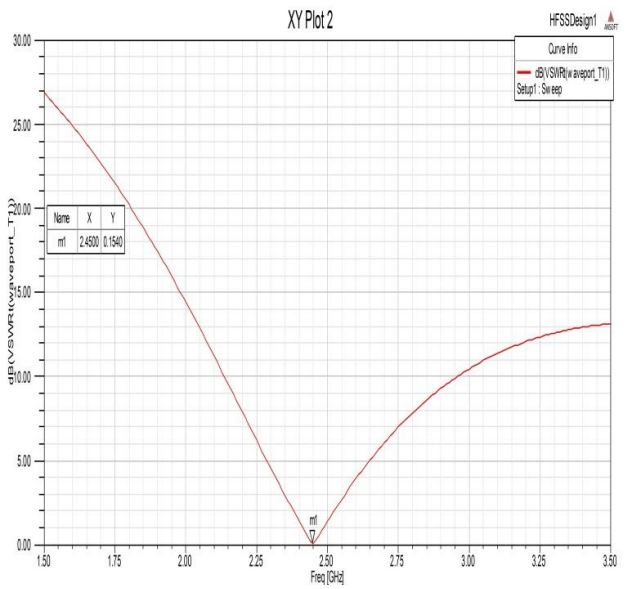

Fig. 9 VSWR of proposed PIFA antenna

C. Comparison of results

The comparison of return loss or S11 for Patch and PIFA antenna for the required resonant frequency of 2.4 GHz is shown in Fig. 10. The return loss of Patch antenna (shown by solid red line) is -30.6570 dB at 2.37 GHz resonant

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frequency and for PIFA antenna (shown by dashed blue line), it is -41.0466 dB at resonant frequency of 2.45 GHz. From the results obtained, PIFA shows better values for return loss as compared to Patch antenna.

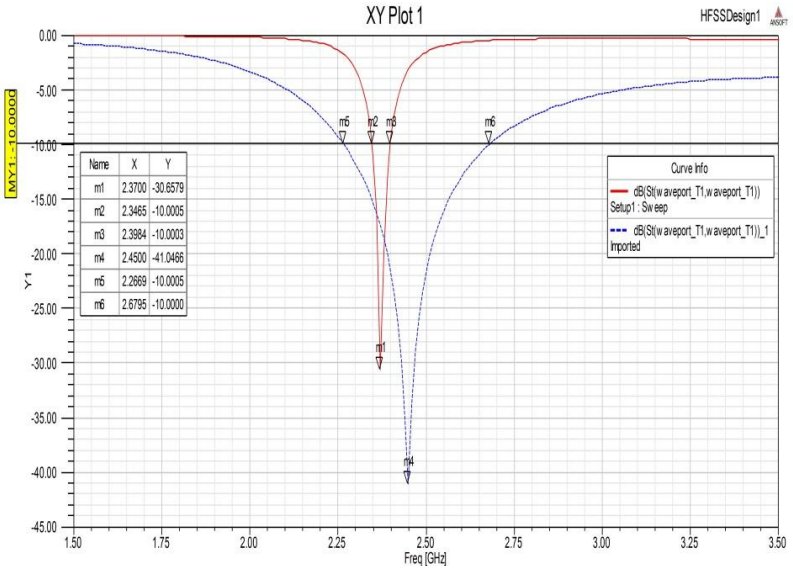

Fig. 10 S11 of Patch antenna (dashed blue) and PIFA antenna (solid red)

TABLE III shows the comparison of results for Patch and PIFA antenna.

TABLE IIIII COMPARISON OF RESULTS

S.No.	Parameters	Patch antenna	PIFA antenna
1	Required Resonant frequency	2.4 GHz	2.4 GHz
2	Resonant frequency (f_0)	2.37 GHz	2.45 GHz
3	Required BW or frequency band	WCS (2.305-2.32 GHz, 2.345-2.36 GHz) and SDR (2.32-2.325 GHz)	
4	Bandwidth (-10dB)	51.9 MHz	412.6 MHz
5	Return loss	-30.6579 dB	-41.0466 dB
6	VSWR	0.5094	0.1540

V. CONCLUSION

In this paper, single band coax-fed rectangular Patch and PIFA antennas for operating frequency of 2.4 GHz were proposed. The simulated results for return loss and VSWR were obtained in Ansoft HFSS v13.0. The return loss values for Patch and PIFA antenna were obtained as -30.6579 dB and -41.0466 dB at the resonant frequency of 2.37 GHz and 2.45 GHz respectively. The values for VSWR for Patch and PIFA antenna at resonant frequency of 2.37 GHz and 2.45 GHz were obtained as 0.5094 and 0.1540 respectively. The resulting impedance bandwidth of these antennas can support WCS and SDR bands. The comparison of Patch and PIFA antenna in terms of return loss was also obtained. From the results, it is revealed that PIFA antenna shows better results for return loss values than Patch antenna.

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