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Compact Thin Broadband Microstrip Patch Antenna for Wireless Communication

Tapas Tewary¹, Smarajit Maity², Sunandan Bhunia³

Assistant Professor, Department of ECE, Academy of Technology, Hooghly, Adisaptagram, West Bengal, India¹

Assistant Professor, Department of AEIE, Academy of Technology, Hooghly, Adisaptagram, West Bengal, India²

Associate Professor, Department of ECE, Central Institute of Technology, Kokrajhar, Assam, India³

ABSTRACT: This paper proposes design and analysis of a compact broadband microstrip patch antenna for wireless communication applications. With the dimension of $40 \times 30 \times 1.6 \text{ mm}^3$ the proposed antenna is printed on both sides of a low cost, reliable FR4 substrate having very low thickness of 1.6 mm, dielectric constant of 4.3 and loss tangent of 0.02. -10 dB impedance bandwidth ranging from 2.12 GHz to 3.87 GHz with single resonance frequency at 2.35 GHz has been observed for this antenna. A bandwidth of 66.8% with VSWR less than 1.5 for the most of the frequency band are obtained for the proposed antenna. Stable radiation patterns in Both E plane and H plane at resonance frequency with very low cross polarization and more than 70% radiation efficiency are achieved. All the simulation results are obtained by using CST Microwave Studio.

KEYWORDS: Microstrip patch antenna, broadband, compact, wireless communication

I. INTRODUCTION

Modern wireless communication systems demand microstrip patch antenna in high frequency (more than 1 GHz) for its various advantages like low cost, compact size, easy integration with other integrated chip etc. But due to some disadvantages like very low bandwidth this type of antenna cannot be used in all type of wireless application [1]. Furthermore multiple antennas cannot be used to satisfy multiple application now a days covering huge bandwidth. So designing planar microstrip patch antenna with broadband may be a solution for this. From Shannon's expression we can conclude that channel capacity can be increased by increasing bandwidth or by increasing signal to noise ratio. But signal to noise ratio increment is not possible always. So a microstrip patch antenna with high -10 dB impedance bandwidth may be designed to address this problem. That is why one of the main objective of the researchers to design antenna having large impedance bandwidth keeping all the parameters in range. Shorting pin method, staggering effect [2], introducing slots on the radiating patch [3-5] etc. are proposed to increase bandwidth of the antenna along with the compactness. Incorporation of slots of different sizes in radiating and the ground plane at suitable positions [6-9] are also proposed to address the above said problems.

In this proposed work an inset fed planar microstrip patch antenna utilizing the defected ground structure in combination with curved radiating plane to achieve broadband operation has been proposed. The simulated peak gain of 4.1 dBi and a large frequency band of 1.75 GHz (2.12 GHz -3.87 GHz) are found. The antenna is simulated by using CST Microwave studio. Simulated results are analysed for confirming the performance of proposed antenna. It is found that the bandwidth of the designed antenna has been increased to 66.8% with attractive compactness.

II. ANTENNA DESIGN METHODOLOGY

The initial width and length of the proposed antenna have been calculated using microstrip antenna equations [10]. The design of proposed antenna radiating plane comprises of two ellipses and a rectangle at the top. This structure is printed on one side of the FR4 substrate having the dimension of $L_s \times W_s \times h$. The length of major axis of lower ellipse is 27.4 mm and that of upper ellipse is 29.6 mm. The length of minor axis of lower ellipse is 12 mm and that of upper ellipse is 24 mm. These two ellipses are partially overlapped. The rectangular portion of the proposed antenna patch has a dimension of $30 \times 7.9 \text{ mm}^2$. The width of the feed line is taken as 3 mm to make the 50Ω characteristics impedance. The proposed antenna is designed by the cheap and most reliable FR4 substrate. This substrate has a relative dielectric constant (ϵ_r) of 4.3 and loss tangent ($\tan \delta$) of 0.02. On the other side of substrate, a rectangular conducting ground plane with full dimension of $L_G \times W_G$ is printed. Two rectangular slots are cut from the ground plane as shown in Fig.2. The dimension of each slot is $18 \times 1.5 \text{ mm}^2$. To achieve the wideband characteristics of the proposed antenna the length,

width and position of the slots on the ground plane have been modified and finally optimized. Fig.1 shows the detailed geometry of the radiating plane and Fig.2 shows the detailed geometry of ground plane of the proposed antenna. All the optimized antenna parameters and also the design parameters along with dimensions have been described in Table I.

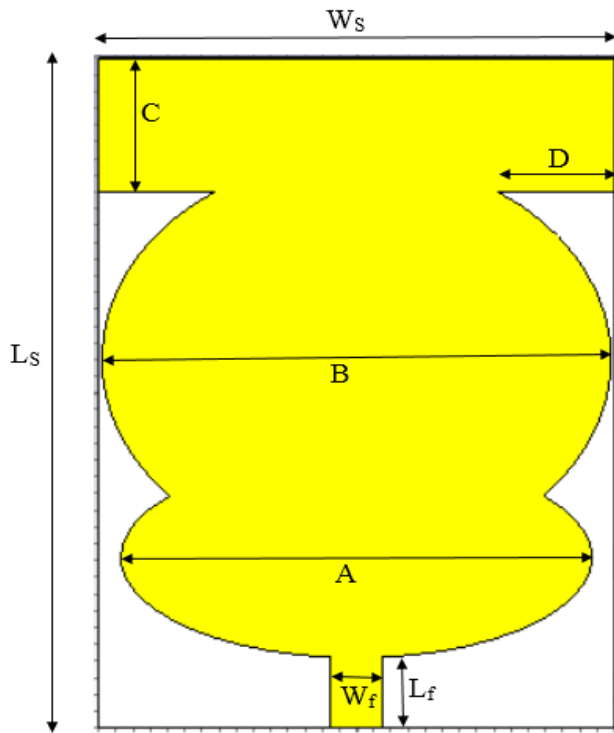


Fig. 1. Structure of radiating plane of the proposed antenna

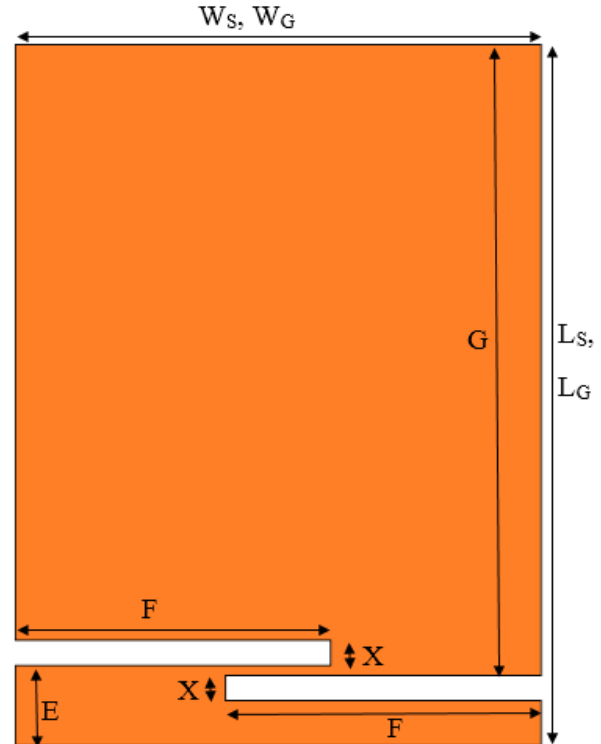


Fig. 2. Structure of the ground plane of the proposed antenna

Table I. Antenna parameter specification

Antenna Parameter	Value	Antenna Parameter	Value	Antenna Parameter	Value
Operating bandwidth	2.12 GHz-3.87 GHz	W_s	30	E	4.5
Substrate	FR4 epoxy	L_s	40	F	18
Substrate Thickness (h)	1.6 mm	W_f	3	G	36
Relative permittivity	4.3	L_f	5	H	1.5
Loss Tangent	0.02	A	27.4	X	40
Characteristic Impedance	50Ω	B	29.6	L_g	30
		C	7.9	W_g	
		D	6		

III. SIMULATION RESULTS AND DISCUSSIONS

All the simulation results of the proposed antenna have been obtained by using a promising antenna design software, CST Microwave Studio. Fig. 3. Illustrates the reflection coefficients of three designed antennas and it also explains how the final design is obtained. If the length of the slots are modified then the bandwidth of the proposed antenna is also modified and it is found that with the increase in length of the slot the bandwidth increases. When the lengths of the slots on the ground plane are 15 mm then a narrow band characteristics is observed as shown in Design 1 and then the bandwidth of the antenna is only 0.75 GHz. When the slot lengths are modified to 17.2 mm then the reflection coefficient shows that the bandwidth of the proposed antenna becomes almost twice the previous one. It is illustrated in Design 2. The operating frequency band ranging from 2.4 GHz to 3.77 GHz for this design. Then the slot lengths are finalized to 18.2 mm (proposed as in Design 3) to obtain wideband nature of the proposed antenna. The reflection coefficients of all these three designs are clearly illustrated in Fig. 3. The simulation result of the design 3 shows that it

has wide impedance bandwidth of 1.75 GHz ranging from 2.12 GHz to 3.87 GHz. The proposed antenna (design 3) has a single resonant frequency located at 2.35 GHz with the reflection coefficient of -35.5dB.

The VSWR of the proposed antenna is less than 2 in the entire operating frequency range and it is shown in Fig. 4. The surface current distribution of the proposed antenna at the resonant frequency of 2.35 GHz is illustrated in Fig. 5(a). From the surface current distribution it can be noted that there is no null point in the feed line at resonance frequency of the proposed antenna. It can also be observed that current intensity is large enough at the resonance frequency. Both the real and imaginary part of z-parameter are described in Fig. 5(b).

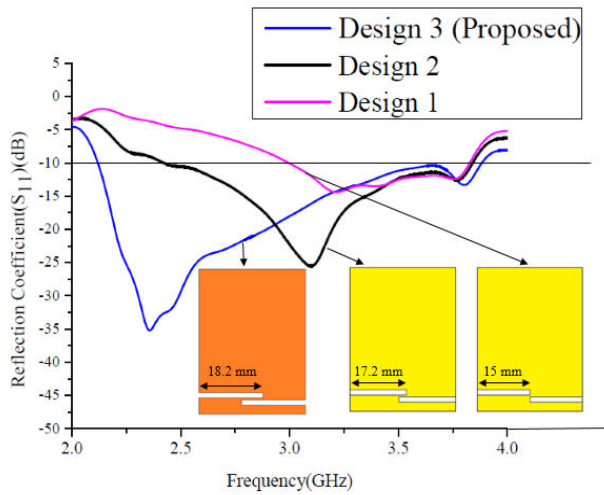


Fig. 3. Reflection coefficient vs. Frequency of the proposed antenna

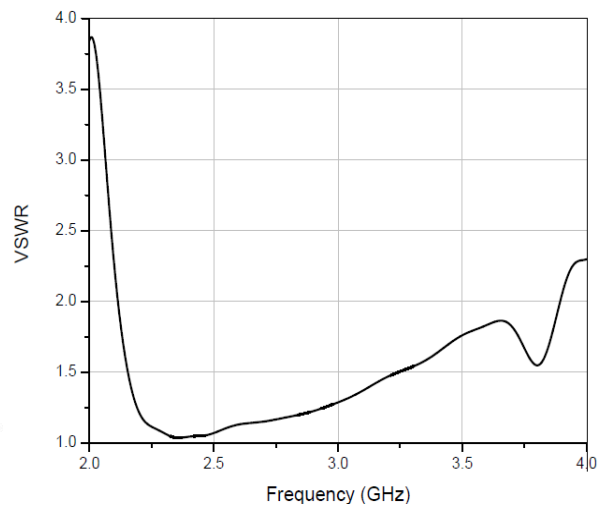
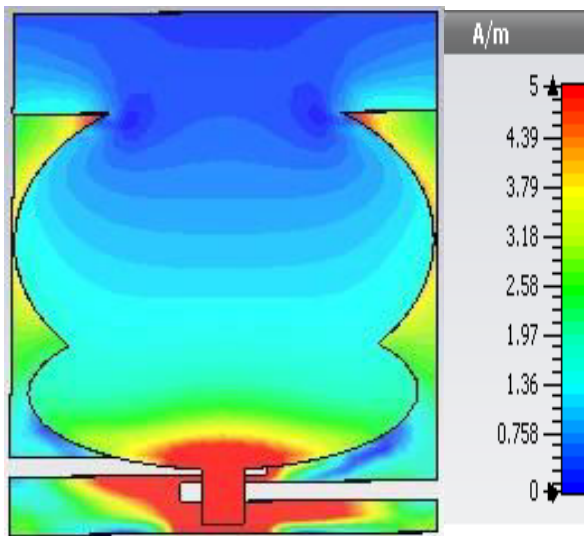
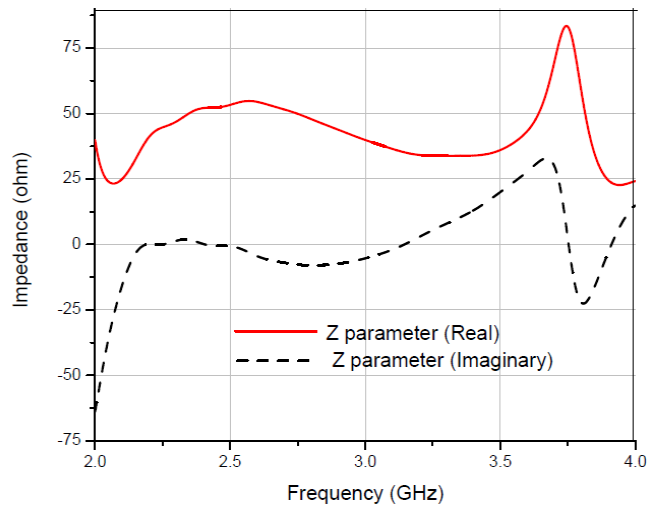


Fig. 4. VSWR vs. Frequency of the proposed antenna



(a)



(b)

Fig. 5.(a) Surface Current distribution of the proposed antenna at 2.35 GHz and (b) corresponding Z parameter

Fig. 6 shows simulated peak gain of 4.1 dBi for the frequency range of 2.12 GHz to 3.4 GHz and minimum gain is 2.6 dBi at 3.75 GHz frequency. Fig. 7 explains the efficiency of the proposed antenna and it is found that the radiation efficiency is around 70% for most of the operating frequency range.

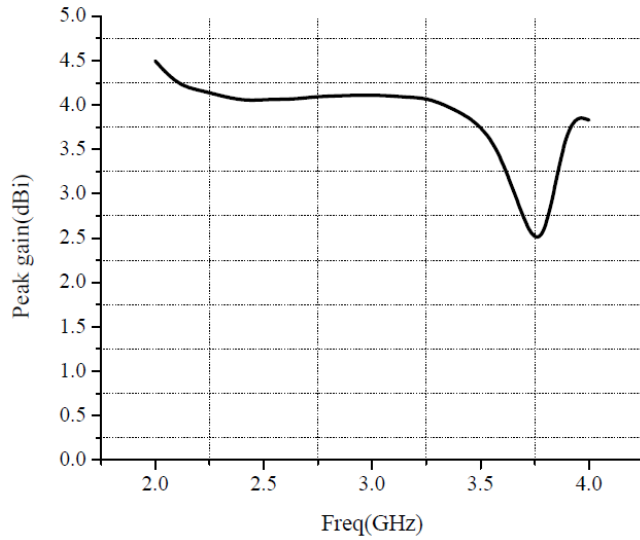


Fig. 6. Peak gain vs. frequency of the proposed antenna

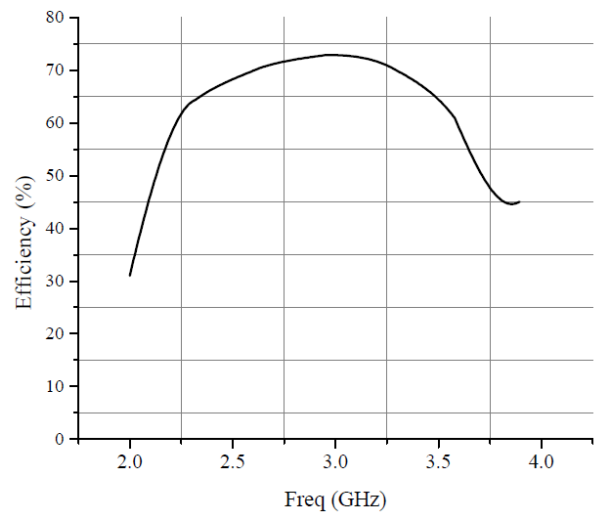
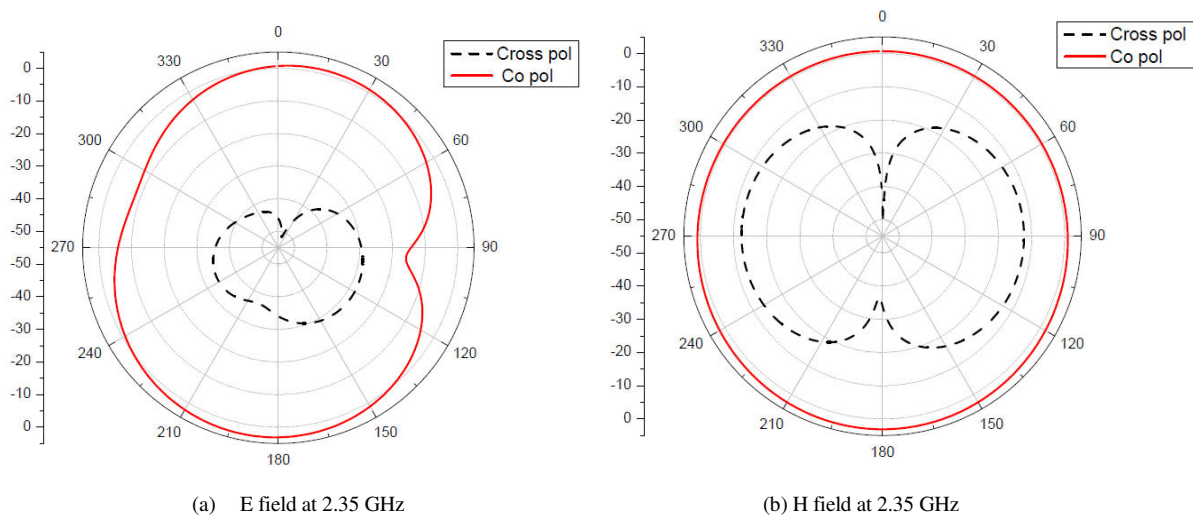


Fig. 7 Efficiency vs. frequency of the proposed antenna



(a) E field at 2.35 GHz

(b) H field at 2.35 GHz

Fig. 8. Radiation pattern of the proposed antenna at 2.35 GHz (a) E plane b) H plane

Co polarization and cross polarization radiation pattern for the E plane and H plane are shown in Fig. 8 and Fig. 9 respectively. It is found that the proposed antenna behaves very well with respect to polarization. The average isolation is about 30 dB in between co polarization and cross polarization in the E plane and this is about 14 dB in the H plane.

TABLE II. Results of all the References and proposed work

Ref. No.	Max (B. W.)	% of B.W.	Dimensions(mm ²)
[4]	(1.01-2.01)GHz	66.2	120 x 120
[5]	(1.61-3.45) GHz	72.7	150 x 150
[6]	(1.46-1.68) GHz	25.31	120 x 120
[7]	(0.7-1.15) GHz	49	120 x 115.2
[8]	(2.99-5.16) GHz	54.79	30 x 20
proposed	(2.12-3.78) GHz	66.8	40 x 30

IV. CONCLUSION

In this work a thin (1.6 mm) compact broadband simple planar microstrip patch antenna is designed, simulated and analysed. CST Microwave studio has been used to simulate the proposed antenna. Due to the defective ground structure and curved radiating plane the bandwidth of the antenna is increased to 66.8%. The proposed antenna exhibits -10 dB impedance bandwidth of 1.75 GHz ranging from 2.12 GHz to 3.87 GHz. Also the simulated peak gain is 4.1 dBi which is much better than the average gain of general microstrip antenna. The proposed antenna is designed using a low cost and reliable FR4 epoxy substrate. So this antenna model can easily be manufactured in large quantities and also can be integrated with ICs with no complexity. This antenna can be considered as a good candidate for wireless applications.

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