

Performance Analysis and Bandwidth Enhancement of Rectangular Microstrip Patch [MSP] Antenna using Compact Double 'L' Slotted Technique for Broadband Applications

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Abstract: In this paper, a wide band double 'L' slotted rectangular Microstrip patch antenna is presented. The major advantage of the approach presented here is enhanced bandwidth. It can be seen that bandwidth of rectangular MSP antenna is increased to a great magnitude when 'L' slots are made on the rectangular patch. Applications where wide bandwidth is required, this designed slotted patch antenna is one of the alternative solutions. The proposed antenna has frequency band (2.07-4.32 GHz) of 2.25 GHz with fractional bandwidth of 70.42%. The gain has been improved up to 5.35 dBi, directivity 5.39 dBi and efficiency 99.7515 %. The proposed double 'L' slotted Microstrip patch antenna is fed by 50Ω Microstrip feed line and suitable for L, S, and C-band operations. The performance of proposed antenna structure is simulated by using IE3D Zealand simulation software based on method of moments.

Keywords: Enhanced bandwidth, compact Microstrip (MS) Patch, calculated ground plane, gain, 50Ω feed line.

I. Introduction

Microstrip patch antennas have drawn the attentiveness of antenna community researchers due to its light weight, low profile, low production cost, conformability and ease of fabrication and integration with solid state devices [1]. But the major drawback of rectangular Microstrip antenna is its narrow bandwidth and lower gain. The bandwidth of Microstrip antenna may be increased using various techniques such as use of a thick or foam substrate, cutting slots or notches like W slot, E shaped, plus shaped patch antenna, introducing the parasitic elements either in coplanar or in stack configuration, defected ground plane and modifying the shape of the radiator patch by introducing the slots [2, 3, 4 and 5]. In this present work the bandwidth of Microstrip antenna is increased By cutting 'L' slots and it is obtained that the bandwidth of 'L' slotted rectangular MSP antenna is much greater than simple rectangular Microstrip antenna. Double 'L' slotted rectangular MSP antenna with Microstrip line feed is shown in Figure1. The width of the Microstrip line was taken as 5.0 mm and the feed length as 5.0 mm. The patch is energized electromagnetically using 50Ω Microstrip feed line [6]. The proposed antenna has been designed on glass epoxy substrate ($\epsilon_r = 4.4$). The substrate material has large influence in determining the size and bandwidth of an antenna. Increasing the dielectric constant decreases the size but lowers the bandwidth and efficiency of the antenna while decreasing the dielectric constant increases the bandwidth but with an increase in size [7,8]. The design frequency of proposed antenna is 2.0 GHz. Different structures are simulated by using IE3D simulation software and it is obtained that rectangular patch with 'L' slots gives wider bandwidth.

The frequency band (2.07-4.32 GHz) of proposed antenna is suitable for broad band applications(1.605-3.381GHz) [9] such as military, wireless communication, satellite communication, global positioning system (GPS), RF devices, WLAN/WI - MAX application [10,11]. Broadband devices are mainly used in our daily lives such as mobile phone, radio, laptops and Microstrip patch antennas plays important role in these devices [12].

II. Antenna Design

For designing a rectangular Microstrip patch antenna, the length and the width are calculated as below [11, 12 and 13].

$$w = \frac{c}{2f_r} \sqrt{\frac{2}{\epsilon_r + 1}} \quad (1)$$

Where c is the velocity of light, ϵ_r is the dielectric constant of substrate, f_r is the antenna design frequency, W is the patch width, and the effective dielectric constant $\epsilon_{r_{eff}}$ is given as [12, 13, 14 and 15]

$$\epsilon_{r_{eff}} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left[1 + 12 \frac{h}{W} \right]^{-\frac{1}{2}} \quad (2)$$

At $h = 1.6$ mm

The extension length ΔL is calculates as [7, 12]

$$\frac{\Delta L}{h} = 0.412 \frac{(\epsilon_{r_{eff}} + 0.3) \left(\frac{W}{h} + 2.64 \right)}{(\epsilon_{r_{eff}} - 2.58) \left(\frac{W}{h} + 0.8 \right)} \quad (3)$$

By using the above mentioned equation we can find the value of actual length of the patch as, [8, 11 and 12]

$$L = \frac{c}{2f_r \sqrt{\epsilon_{r_{eff}}}} - 2\Delta L \quad (4)$$

The length and the width of the ground plane can be calculated as [10, 12 and 13]

$$L_g = 6h + L \quad (5)$$

$$W_g = 6h + W \quad (6)$$

III. Antenna Design Specifications

The design of proposed antenna is shown in Figure1. The proposed antenna is designed by using glass epoxy substrate which has a dielectric constant 4.4 and the design frequency is 2.0 GHz. Height of the dielectric substrate is 1.6 mm and loss tangent $\tan \delta$ is 0.0013. Antenna is fed through a line feed of length 3.8 mm and width 4.8 mm which is energized by 50Ω Microstrip feed line. All the specifications are given in the table1. (All lengths are in mm and frequency in GHz).

Table 1: Parameters For Antenna Design.

Sr.No.	Parameters	Value
1.	Design frequency f_r	2.0
2.	Dielectric constant ϵ_r	4.4
3.	Substrate height	1.6
4.	Loss tangent , $\tan \delta$.0013

Table 2: Designed Structure parameters

Sr.No.	Parameters	Value
1.	Ground plane width , a	55
2.	Ground plane length , b	44
3.	Patch width , c	45.4
4.	Patch length , d	34.4
5.	e	35
6.	f	25
7.	g	20
8.	h	5

9.	i	10.6
10.	j	19.3
11.	k	24
12.	l	13.4
13.	m	4
14.	n	6
15.	o	5
16.	p	5
17.	q	13

V. Antenna Design Procedure and Layout

All the dimensions of rectangular Microstrip antenna should be calculated very carefully by using the equations 1, 2, 3, 4, 5 and 6. Design frequency is 2.0 GHz taken for designing a proposed broad band double 'L' slotted Microstrip patch antenna. One regular 'L' slot with one inverted 'L' slot.

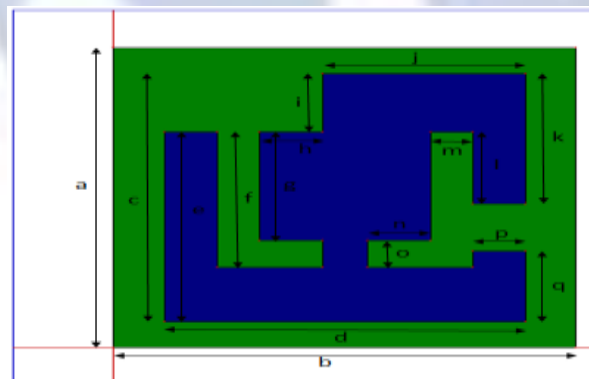


Figure 1. Geometry of proposed Microstrip antenna

VI. Simulation Result and Discussion

The narrow bandwidth of Microstrip antenna is one of the important features that restrict its wide usage. In the present work we are tried to increase the bandwidth of rectangular Microstrip antenna by successively cutting 'L' slots [14]. From the above available performance results it is clear that rectangular patch antenna with double 'L' slots plies highest bandwidth.. The maximum gain of the antenna has been improved up to 5.35dBi, directivity improved up to 5.39dBi at the third peak frequency of 4.04 GHz. Efficiency of the antenna is found to be 99.75%, and the VSWR of the antenna is in

between 1 to 2 over the entire frequency band which shows that there is a proper impedance matching. The maximum return loss of the proposed antenna is 26.05 dBi at 2.41 GHz.

The simulation performance of proposed micro strip patch antenna is analyzed by using IE3D simulation software at the selected design frequency of 2.0GHz. The graph of return loss Vs frequency is taken at the maximum frequency of 4.5GHz which is shown in Figure 2.

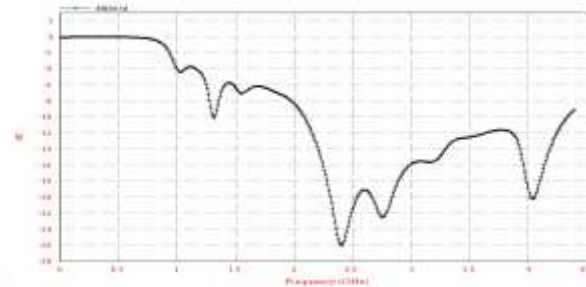


Figure 2: Return loss v/s frequency graph.

In Figure 3, the graph of Gain Vs Frequency shows the total field gain of the MSP antenna and obtains max. gain of antenna is 5.3486 dBi at frequency 4.04 GHz.

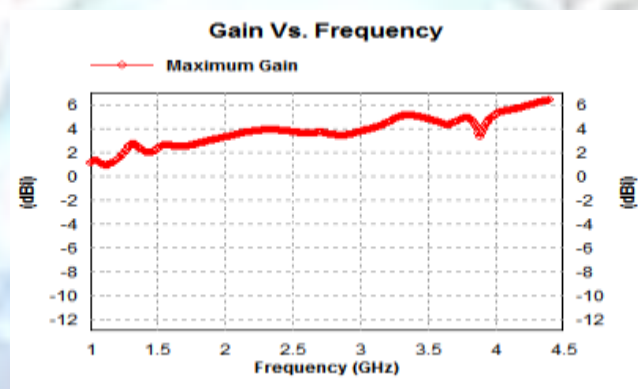


Figure 3. Gain vs. frequency plot.

In Figure 4, the graph of VSWR Vs Frequency represents that the bandwidth of design antenna is useful or not. The obtain VSWR is 1.105 at resonant frequency of 2.41 GHz.

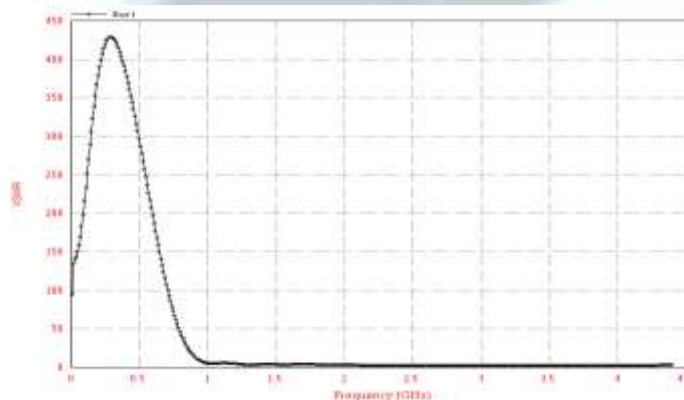


Figure 4. VSWR of proposed antenna

In Figure 5, the graph of total field Directivity Vs Frequency represents the ratio of radiation intensity in a given direction from the antenna to the radiation intensity averaged over all direction [11]. The obtain directivity of antenna is 5.3908 dBi at frequency 4.04 GHz.

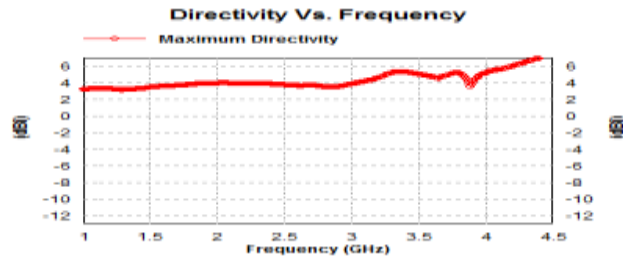


Figure 5. Directivity v/s frequency plot

The smith chart is very useful when solving transmission problems. The real utility of the Smith chart, it can be used to convert from reflection coefficients to normalized impedances (or admittances), and vice versa. Smith chart of dual 'L' slot rectangular microstrip antenna for bandwidth improvement at 2.4 GHz. Fig.6 shows the impedance variation in the simulated frequency range and received impedance matching for proposed antenna at characteristic impedance.

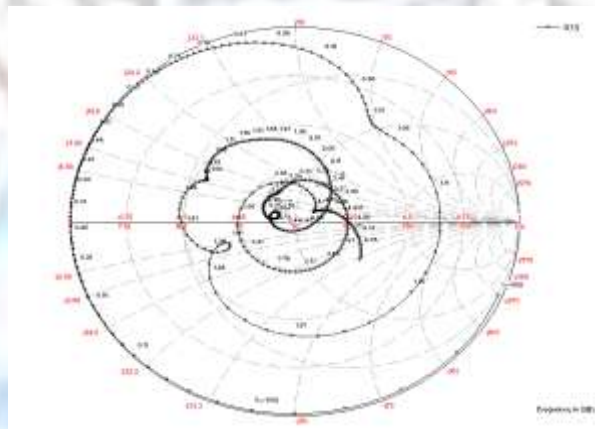


Figure 6. Smith chart

In Figure 7, the plotted graph of 2D radiation pattern of antenna represents radiating all power in one direction therefore design antenna has unidirectional radiation pattern. 2D radiation pattern of antenna is shown at resonant frequency 2.41GHz and $\phi=0(\text{deg})$, $\phi=90(\text{deg})$.

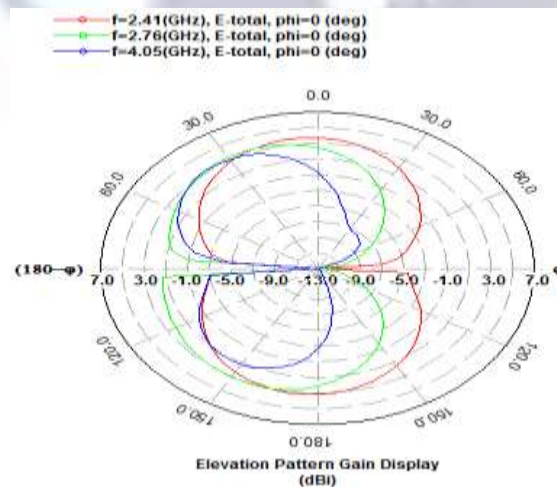


Figure 7: 2D radiation pattern of antenna

In Figure 8, the plotted graph of Efficiency Vs Frequency represents radiating efficiency and antenna efficiency. The obtain percentage antenna efficiency is 99.7515% at 2.41 GHz.

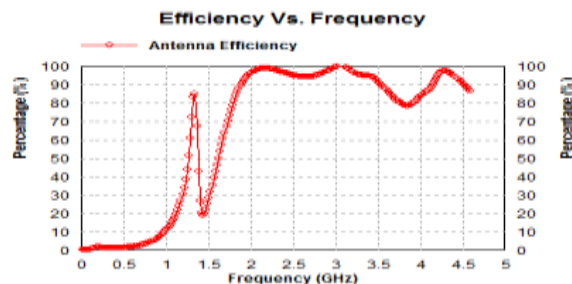


Figure 8. Efficiency graph of proposed antenna.

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Conclusion

The performance analysis and characteristics of compact double 'L' slotted patch antenna dimensional parameters are studied through simulation results. In general, the impedance bandwidth of the traditional Microstrip antenna is only a few percent (7% -8%) [9]. Therefore, it becomes very important to develop a technique to increase the bandwidth of the Microstrip antenna. Proposed antenna provides wide frequency band with 70.42% fractional bandwidth. The proposed antenna has been designed on glass epoxy substrate to give a maximum radiating efficiency of about 99.7515% and high gain of about 5.3486 dBi.

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