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Analysis and bandwidth enhancement by cutting pi and rectangular slot in rectangular microstrip antenna for broad band applications

Ashish Chaudhary[1], Sunil Kumar[2], D. C. Dhubkariya
[1,2,3]Digital Communication, B.I.E.T., Jhansi, U.P., India

Abstract: This article proposes, single feed compact slotted patch antenna. It can be seen that bandwidth of Microstrip antenna is increased up to great extant by cutting two equal slots which are same as π structure added with rectangular slots. In some applications in which the increased bandwidth is needed, designed antenna is one of the alternative solutions. The proposed antenna operates in frequency band (1.88-3.44 GHz) the fractional bandwidth is 58.88%. The gain has been improved up to 5.11dBi, directivity 5.39dBi and efficiency 97.216%. The proposed Microstrip antenna is fed by 50Ω Microstrip feed line .The designed structures and performance of different structures are simulated and compared by using IE3D Zealand simulation software based on method of moments.

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

I. Introduction

Microstrip patch antennas are widely implemented in many applications in wireless communication due to their attractive features [1]. They are extremely compatible for embedded antennas in handheld wireless devices [2]. Some of their principal advantages are light weight, low volume, low fabrication cost, easy to mount, low profile, conformal, linear and circular polarization possible, easy to implement by position of feed, dual frequency use possible, solid state devices easily integrated. On the other side, the greatest disadvantage of the microstrip Patch antennas is its low bandwidth which can be as low as (2% - 5%). Therefore, it becomes very important to develop broadband technique to increase the bandwidth of the microstrip antenna.

The bandwidth of the Microstrip Patch Antennas increases with an increase in the substrate thickness *h* or with a decrease in the dielectric constant, $\in_r$. However, there is a practical limit on increasing the *h*, and if increased beyond 0.1λ0, surface-wave propagation takes place, resulting in degradation in antenna performance. Also, with an increase in *h*, the probe inductance increases and probe compensation techniques have to be employed to obtain impedance matching.

The bandwidth of Microstrip antenna may be increased by cutting slots or notches like U slot, E shaped H shaped [3, 4, and 5]. In the present work the bandwidth of Microstrip antenna is increased by cutting dual pi and rectangular slot and it is obtained that the bandwidth of rectangular Microstrip antenna with dual pi and rectangular slot is many times greater than simple rectangular Microstrip antenna. Dual pi and rectangular slot Microstrip antenna is shown in Figure1.

The width of the Microstrip line was taken as 4 mm and the feed length as 4.8 mm. The patch is energized electromagnetically using 50 ohm Microstrip feed line [6]. The proposed antenna has been designed on glass epoxy substrate ($\in_r$ = 4.4) [7]. 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. The design frequency of proposed antenna is 2.4 GHz. Designed antenna is simulated and analyzed by using IE3D simulation software.

The frequency band(1.88-3.44 GHz) of proposed antenna is suitable for broad band applications[8] (1.605-3.381GHz) [16], such as military, wireless communication, satellite communication, global positioning system (GPS), RF devices, WLAN/WI -MAX application [9,10].

II. Design consideration of proposed antenna

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

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

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 [11, 12]

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

At h = 1.6mm

The extension length ΔL is calculates as

$$\frac{\Delta L}{h} = 0.412\frac{\left(\epsilon_{r_{eff}}+0.3\right)\left(\frac{W}{h}+.264\right)}{\left(\epsilon_{r_{eff}}-.258\right)\left(\frac{W}{h}+0.8\right)} \quad (3)$$

By using the above mentioned equation we can find the value of actual length of the patch as,

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

The length and the width of the ground plane can be calculated as [11, 12]

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

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

III. Parameter selection and design

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 2.4 GHz.
Height of the dielectric substrate is 1.6 mm and loss tangent *tan* δ is 0.0013. Antenna is fed through a line feed of length 4.8 mm and width 4mm 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: Antenna parameter specifications.

S.No.	ANTENNA PARAMETER	SPECIFICATION
1.	Design frequency f_r	2.4
2.	Dielectric constant ϵ_r	4.4
3.	Substrate height	1.6

Table 2 Antenna design specifications

S.No.	ANTENNA parameters	Value
1.	Patch width W_p	38.03
2.	Patch length L_p	28.3
3.	Ground plane width W_g	47.6
4.	Ground plane length L_g	37.9
5.	A	2.5
6.	B	1
7.	C	5
8.	D	10
9.	E	4
10.	f	6
11.	g	5.075
12.	h	20
13.	i	12.03
14.	j	2
15.	l	9.15

IV. Antenna Design Procedure

All the dimensions of proposed antenna should be calculated very carefully by using the equations 1, 2, 3, 4, 5 and 6. Design frequency is 2.4 GHz taken. For making proposed antenna two pi shape slots are cut followed by rectangular slot. Feed and slots are varied to obtain wide bandwidth. The improved and proposed design is shown in Figure: 1.

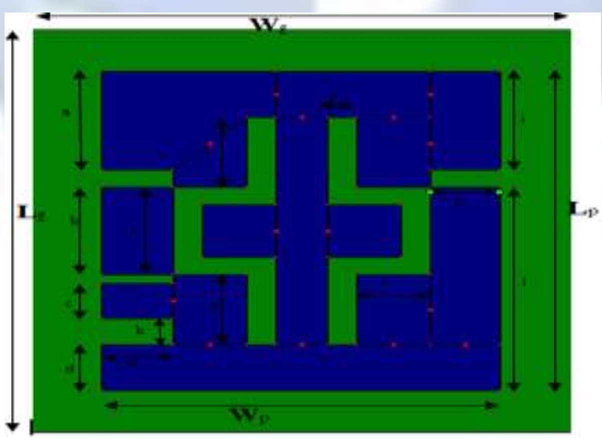

Figure 1: Geometry of proposed Microstrip antenna.

V. Simulation result and discussion

Microstrip antennas are used in a broad range of applications from communication systems to biomedical system, primarily due to several attractive properties such as light weight, low profile, low production cost, conformability, reproducibility, reliability, and ease in fabrication and integration with solid state devices. The narrow bandwidth of Microstrip antenna is one of the important features that restrict its wide usage**.** In the present work we tried to increase the bandwidth of rectangular Microstrip antenna by cutting dual pi and rectangular slot. From the above comparison results it is clear that rectangular patch antenna with dual pi and rectangular slot Microstrip patch antenna provides highest bandwidth. The maximum gain of the antenna has been improved up to 4.71dBi, directivity improved up to 4.8dBi, efficiency of the antenna is found to be 98.21%, 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 return loss of the proposed antenna is 40dBi.

The simulation performance of proposed micro strip patch antenna is analyzed by using IE3D version9 software at select design frequency of 2.4GHz.

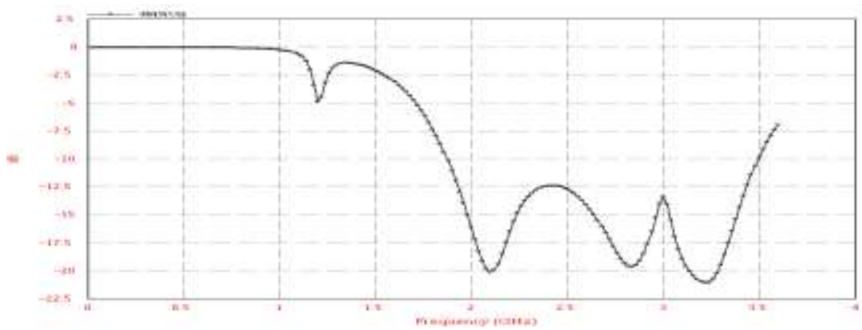

Figure 2: Return loss v/s frequency graph.

Figure 3, shows the VSWR of designed antenna. 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 designed antenna exhibits broadband frequencies with VSWR < 2.2.

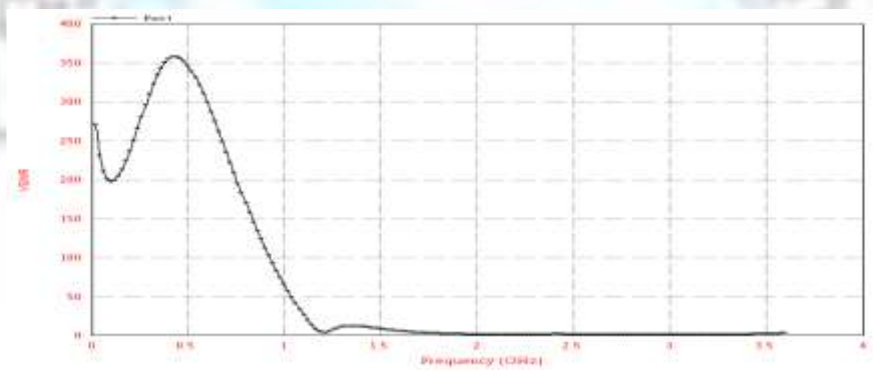

Figure 3. VSWR of proposed antenna

Gain Vs. Frequency graph of the microstrip dual pi slot added with rectangular slots shown in figure 4. The maximum gain of the antenna has been improved up to 5 dBi. Gain is more than that of rectangular microstrip patch antenna.

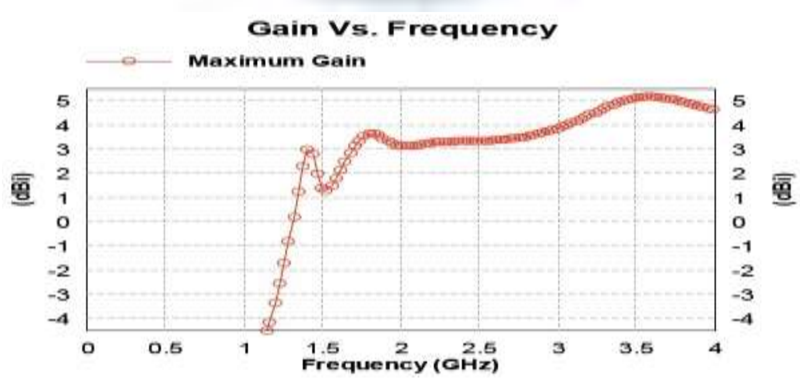

Figure 4: Gain vs. frequency plot.

Efficiency vs. frequency graph for designed rectangular element direct coupled microstip patch antenna is shown in Fig. 5.

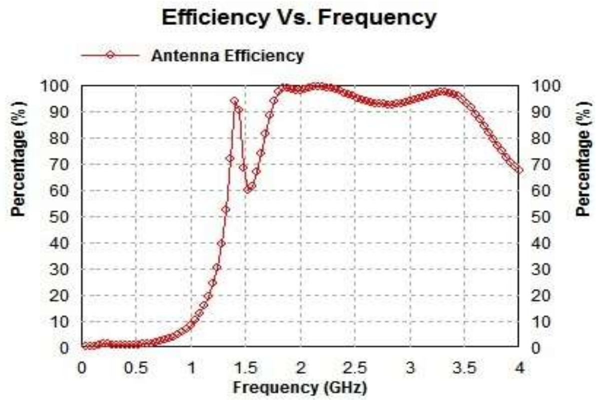

Figure 5: Efficiency graph of proposed antenna.

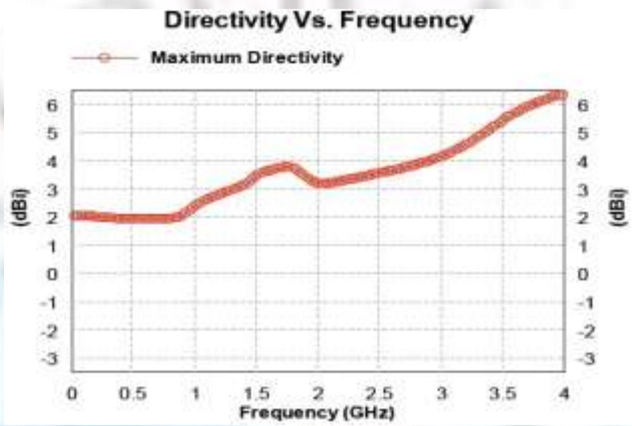

Figure 6: Directivity v/s frequency plot

Directivity Vs frequency graph is shown in figure 6. Directivity of proposed antenna is improved to 6.39dBi.

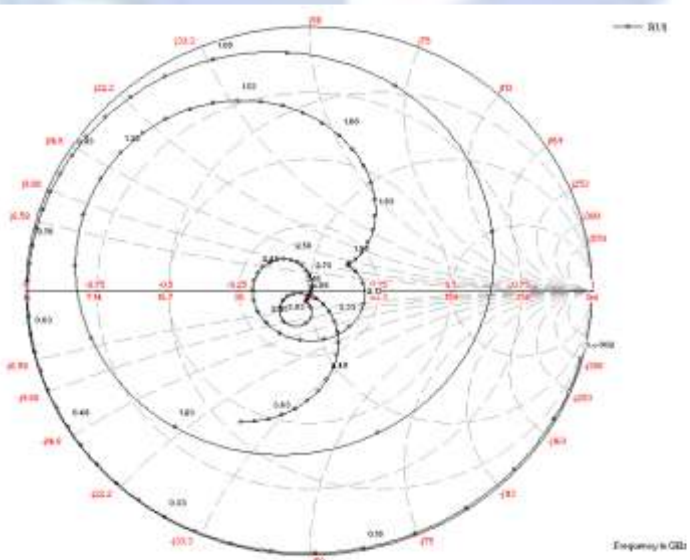

Figure 7: Smith chart

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 pi sot rectangular microstrip antenna for bandwidth improvement at 2.4 GHz. Figure.7 shows the impedance variation in the simulated frequency range and received impedance matching for proposed antenna at characteristic impedance.

And the radiation pattern of the microstrip square patch antenna is shown in figure 8.

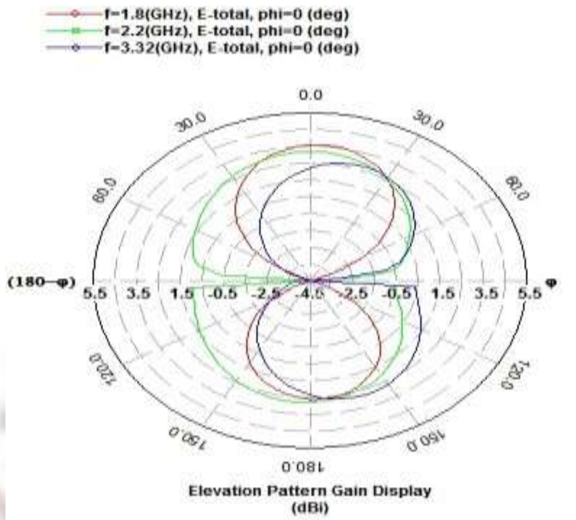

Figure 8: 2D radiation pattern of antenna

VI. Acknowledgment

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VII. Conclusion

A dual pi-slot patch antenna has been designed and simulated using IE3D Zealand simulation software. The comparative analysis and characteristics of compact dual pi added with rectangular slot Microstrip patch antenna are studied. In general, the impedance bandwidth of the traditional Microstrip antenna is only a few percent (2% -5%) [18]. Therefore, it becomes very important to develop a technique to increase the bandwidth of the Microstrip antenna. Proposed antenna provides 58.58% fractional bandwidth. The proposed antenna has been designed on glass epoxy substrate to give a maximum radiating efficiency of about 98.12% and high gain of about 4.71dBi.

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