International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2015): 78.96 | Impact Factor (2015): 6.391

Enhancing the Bandwidth and Minimization of Return Loss of U Shaped Microstrip Patch Antenna for Wideband Applications

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Abstract: *A simple design of U- shaped microstrip patch antenna with wide band characteristics is introduced in this paper. The analysis and simulation results of this design indicates that the proposed antenna exhibits wide band characteristics. The antenna patch is designed on the substrate having thickness of 1.6 mm, relative permittivity of 4.2 and loss tangent of 0.0013. The antenna utilizes the 50 Ω microstrip line feeding technique. IE3D software package of Zeland is used for the simulation of proposed antenna design. The U shaped microstrip patch antenna is designed in such a way that it achieves a wide bandwidth of 77.70% (VSWR<2) and minimum return loss of -64.42 dB at 2.156 GHz resonant frequency.*

Keyword: Microstrip patch antenna, U shape, Microstrip Line feed, IE3D, Return Loss.

1. Introduction

Microstrip patch antenna are becoming useful increasingly because they can be printed onto a circuit board as well as they have some other advantages like low profile, easy fabrication, light weight and low manufacturing cost etc. Due to these attractive characteristics, microstrip patch antennas are very widespread within wireless industries and where rapidly increasing the demand of such light weight and compact antennas. Basically, microstrip patch antenna is a dielectric substrate panel sandwiched in between two conducting layers. The lower conducting layer is called ground plane and the upper conducting layer is known as patch.

However, microstrip patch antennas have drawbacks including narrow bandwidth, low power handling capability and low gain. But with technology advancement and extensive researches into this area these problems are being gradually overcome. There are many well known techniques for enhancing the bandwidth of these antennas, including increase of substrate thickness, the use of different feeding techniques, use of low dielectric substrates and the use of multiple resonators.

A wideband Microstrip patch antenna with microstrip feed line technique is presented in this paper. We have cut down a rectangular slot on patch to give it a shape of U. The proper optimization of proposed antenna design with varying the dimension of rectangular slot, results minimized return loss along with enhanced bandwidth of antenna.

2. Antenna Design

In designing the antenna, it is necessary to choose a suitable dielectric substrate of appropriate thickness (t), dielectric constant and loss tangent. The shape of patch, dielectric constant and thickness of substrate, feeding techniques are important factors which affects the performance of the microstrip patch antenna.

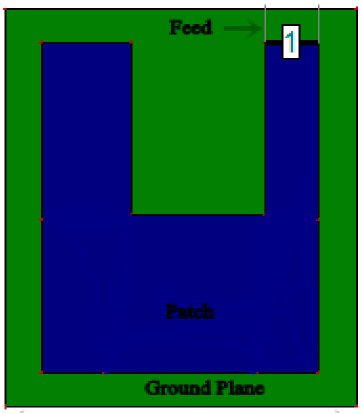

Figure 1 (a): Top view of antenna

The mathematical equations for calculating the dimension of radiating patch antenna and size of ground plane are given below (1-6).

The width of radiating patch is calculated by [12]

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

The effective dielectric constant is calculated by [13]

$$\epsilon_{reff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{-\frac{1}{2}} \tag{2}$$

The length extension is given by [5, 8]

$$\Delta L = 0.412h\frac{[\epsilon_{reff}+0.3]\left[\frac{W}{h}+0.264\right]}{[\epsilon_{reff}-0.258]\left[\frac{W}{h}+0.8\right]} \tag{3}$$

Length of radiating patch is calculated by [2]

$$L = \frac{c}{2f_r\sqrt{\epsilon_{reff}}} - 2\Delta L \tag{4}$$

Length and width of ground plane is calculated by [8]

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

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

Where fr is the operating frequency, c is the velocity of light in the free space, W and L are the width and length of patch respectively, ε_r is the relative dielectric constant of the substrate and ΔL is the length extension, W_g and L_g are the width and length of ground plane respectively.

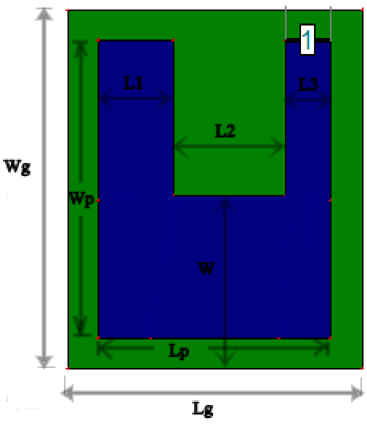

Figure 1 (b): Geometry of proposed antenna

The top view and geometry of the proposed antenna are presented in figure 1(a) and 1(b). It comprise of a finite ground plane having size of 46 mm x 56 mm. A slot of size 17.5 mm x 24.2 mm, etched on the rectangular shaped patch of size 36.4 mm x 46.4 mm.

The dielectric constant of the substrate is closely related with the bandwidth and the size of the microstrip patch antenna. Low dielectric constant of the substrate results wide bandwidth, while the high dielectric constant of the substrate results in smaller size of antenna. A trade-off relationship exists between antenna size and bandwidth [8]. The patch is fed by a 50 Ω microstrip line feed.

Table 1 indicates the optimized design parameter for the proposed antenna.

Table1: The design parameter of the proposed optimized antenna

Parameter	Value(mm)	Parameter	Value(mm)
W_g	56	L_1	11.7
L_g	46	L_2	17.5
W_p	46.4	L_3	7.2
L_p	36.4	h	1.6
W	27		
Dielectric constant = 4.2		Loss tangent = 0.0013	

It is a challenging work to design a compact antenna operating with a wide impedance bandwidth which satisfies the demand of advanced wireless technology. Selecting the suitable slot shape, proper feeding technique and suitable dielectric constant, enhancement in bandwidth can be obtained.

3. Results and Discussions

"IE3D" 9.0.0 version of Zeland is used for the simulation and optimization of this antenna design. Figure 2 shows the simulated -10 dB return loss curve of the proposed antenna which resonate at frequency **2.156 GHz** and also obtained the enhanced impedance bandwidth of **77.70 %** with minimized return loss **-64.42 dB.** The figure 3 shows the VSWR curve, simulated on IE3D. The simulated radiation patterns of the elevation and azimuth of the proposed antenna are shown in figure 4.

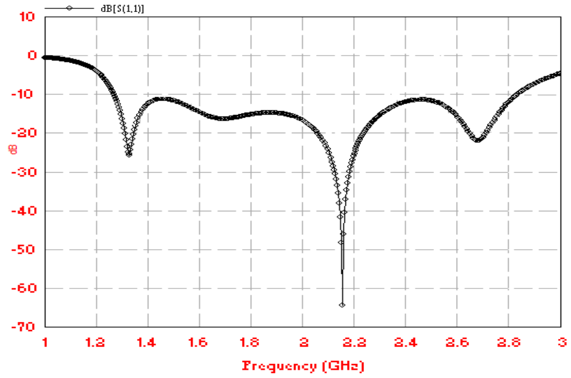

Figure 2: Simulated return loss of proposed antenna

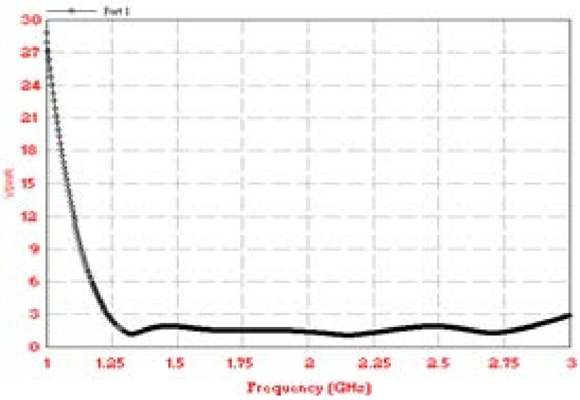

Figure 3: Simulated VSWR of the proposed antenna

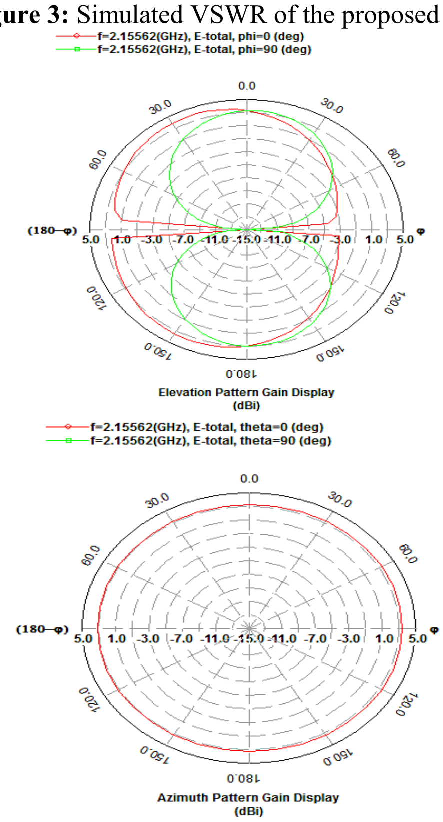

Figure 4: Simulated radiation pattern of the optimized proposed antenna. (a) Elevation pattern, (b) Azimuth pattern

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4. Sensitivity Analysis

A comprehensive numerical sensitivity analysis has been done in order to understand the effects of various dimensional parameters and to optimized the performance of the proposed antenna. The outcomes indicate that the minimization of return loss and bandwidth enhancement is closely depends on L_1, L_2 and L_3. The comparison of the simulated return loss curves for different lengths of W, L_1, L_3 is performed here.

The figure 5 shows the comparison of return loss curves for W = 26.2 mm with variations in L_1 and L_3 and the optimum values for (W, L_1, L_3) is (26.2, 12.2, 7.2) mm. Table 2 shows the corresponding comparison data.

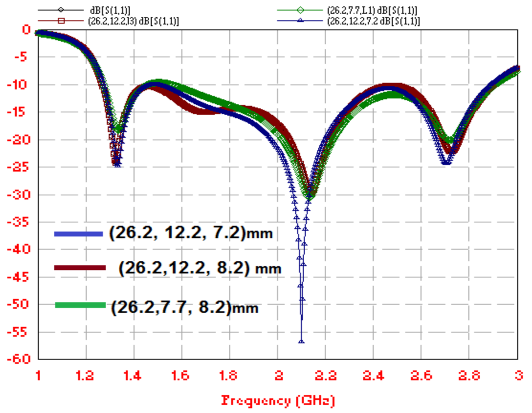

Figure 5: Simulated return loss of the proposed antenna with different lengths of L_1, L_3

Table 2: The simulated bandwidths and return loss for various L_1, L_3, W=26.2 mm

L_1 (mm)	L_3 (mm)	f_l (GHz)	f_h (GHz)	*Bandwidth*	*Return loss*
12.2	8.2	1.267	2.904	78.49%	-29.85
8.2	7.7	1.553	2.92	61.122%	-30.58
12.2	7.2	1.273	2.896	77.86%	-57.01

The simulated return loss curve for different L_1 and L_3 is shown in figure 6. It is clear that these parameter affects the performance of the antenna. The optimum value of (W, L_1, L_3) is (27, 11.7, 7.2) mm. The impedance bandwidth along with return loss for different dimensions are summarized in table 3.

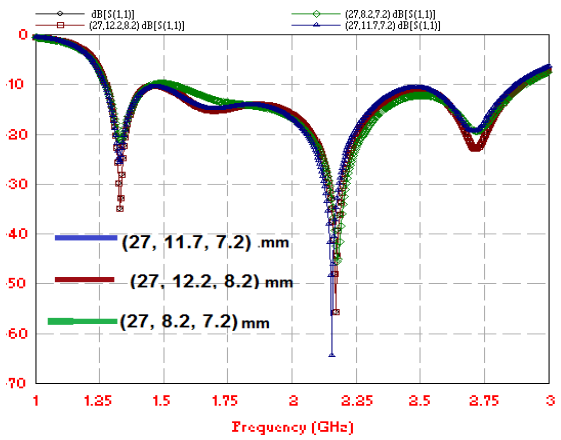

Figure 6: Simulated return loss of the proposed antenna with different dimension of L_1, L_3 and W = 27 mm

Table 3: The simulated bandwidths and return loss for various L_1, L_3, W=27 mm

L_1 (mm)	L_3 (mm)	f_l (GHz)	f_h (GHz)	Bandwidth	Return loss
12.2	8.2	1.271	2.9	78.11%	-55.83
8.2	7.2	1.518	2.912	62.93%	-45.68
11.7	7.2	1.27	2.884	77.70%	-64.42

The simulated return loss curve for W=28 mm and different dimension of L_1, L_3 is shown in figure 7 and the optimum value for (W, L_1, L_3) mm is (28, 7.2, 8.2) mm. The impedance bandwidth for different dimensions of L_1, L_3 are summarized in table 4.

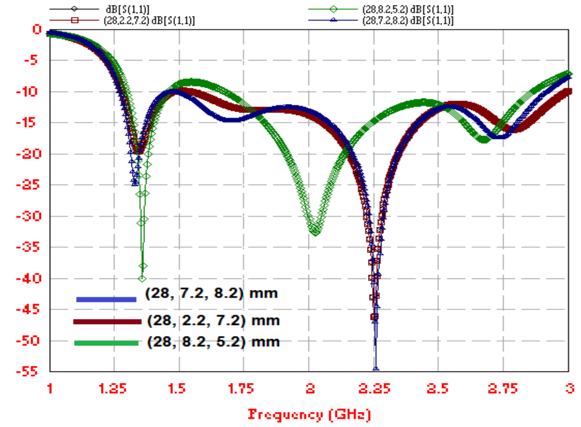

Figure 7: Simulated return loss of proposed antenna with different dimension of L_1, L_3 and W=28 mm.

Table 4: The simulated bandwidth and return loss for different L_1, L_3

L_1 (mm)	L_3 (mm)	f_l (GHz)	f_h (GHz)	Bandwidth	Return loss
2.2	7.2	1.541	3	64.25%	-46.11
8.2	5.2	1.673	2.872	52.76%	-40.16
7.2	8.2	1.267	2.921	78.98%	-54.73

Now, we have introduce the combine affect of dimensional parameters W, L_1, L_3. The variations in W, L_1, L_3 their respective bandwidth and return loss are summarized in table 5.

Table 5: The variation in W, L_1, L_2 and their respective impedance bandwith and return loss (dB)

(mm)	(L_1,L_3) (mm)	f_l (GHz)	f_h (GHz)	Band-width	Return loss
26.2	12.2,7.2	1.273	2.896	77.86%	-57.01
27	11.7,7.2	1.27	2.884	77.70%	-64.42
28	7.2,8.2	1.267	2.921	78.98%	-54.73
29	16.7,8.2	1.313	2.864	74.26%	-53.12

The optimum value of (W, L_1, L_3) is (27, 11.7, 7.2) mm. The comparison of simulated impedance bandwidth versus return loss of these different parameters is shown below in figure 8.

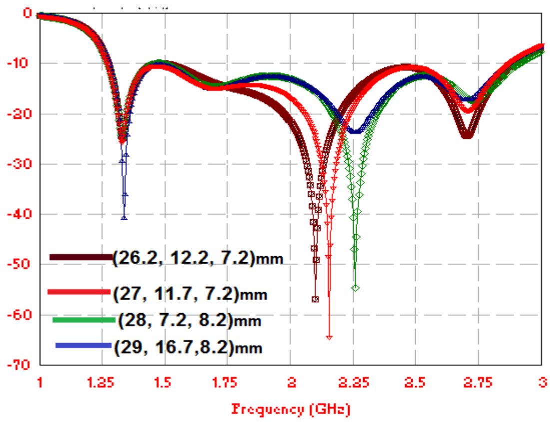

Figure 8: The simulated impedance bandwidth versus return loss of the proposed antenna for different dimensional parameters

The simulated 3D pattern, gain, directivity and efficiency of optimized antenna design are shown in figure 10, 11, 12 and figure13.

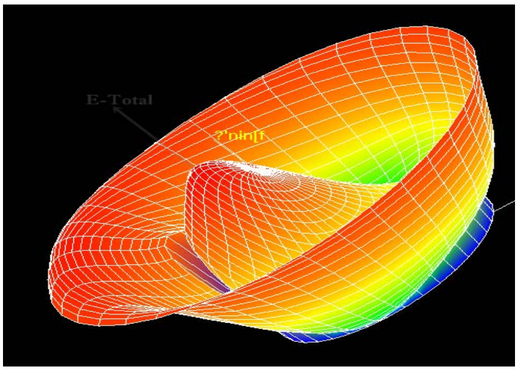

Figure 10: Simulated 3D pattern of the optimized proposed antenna

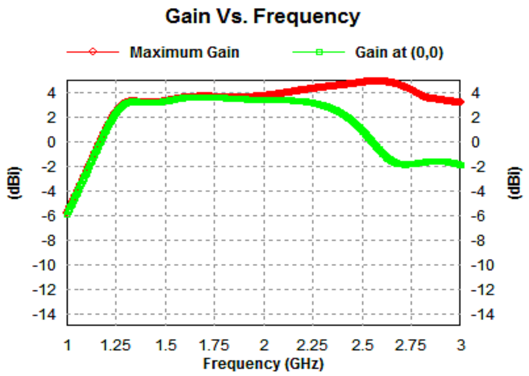

Figure 11: Simulated gain of the optimized proposed antenna

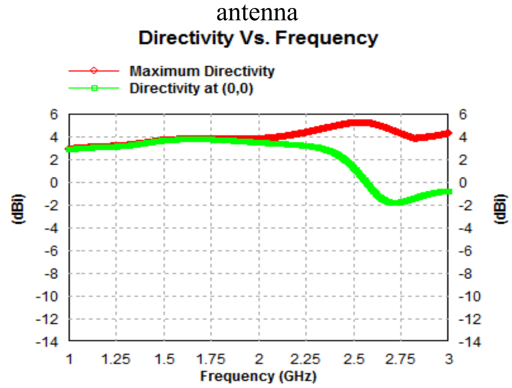

Figure 12: Simulated directivity of the optimized proposed antenna

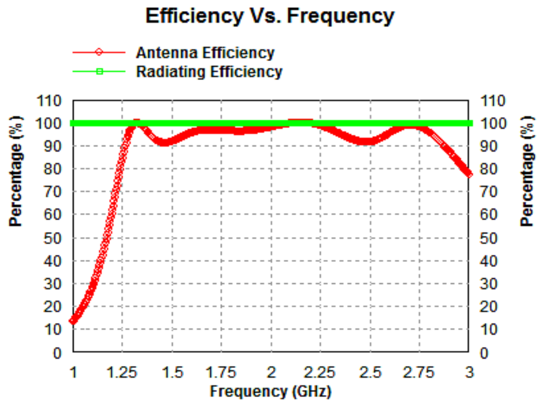

Figure 13: Simulated efficiency of the optimized proposed antenna

5. Conclusion

In this paper, a comprehensive parametric study has been carried out to understand the effects of various dimensional parameters and to optimized the performance of the final proposed antenna design. After the simulation, the proposed Microstrip patch antenna occupies **1.27 GHz –2.884 GHz** frequency band. The proposed antenna structure results enhanced bandwidth of **77.70%** at – 10 dB return loss. The -10 dB return loss is also minimized to **-64.42dB** and antenna resonates at **2.156 GHz**. The proposed antenna also attains a good amount of gain i.e. **4.02129 dBi**, directivity of **4.02129 dBi**, antenna efficiency of **100%** and radiation efficiency of **100 %.**

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