Enhancement of Bandwidth of U-shape Loaded Microstrip Patch Antenna According to 802.11b Standard

Fadel A. M. Alaswad [1*], Marai M. Abousetta [2*], Mohamed A. S. Alshushan [3*]
[1] fadel.abu83@gmail.com, [2] m.abousetta59@yahoo.co.uk, [3] mohammedsaad1318@gmail.com
[1] Department of Communication, Collage of electronic technology, Bani Walid, Libya
[2] Libyan Academy, Tripoli , Libya
[3] Department of Electric and Electronics, College of engineering, Sabratha University, Libya

ABSTRACT

The bandwidth of microstrip antennas is proportional to the thickness of the substrate that used. Since most substrates are very thin in terms of wavelengths, the bandwidth is usually small. To enhance the bandwidth, a new design of rectangular microstrip patch antenna is presented. The proposed geometry consists of a rectangular shaped ground plane structure with a U- slot loaded patch layer. The aim of this is to design a single, double and triple U slotted rectangular patch antenna and compare its performance with non-slotted rectangular microstrip patch antenna. The antennas were designed and simulated using advanced design software. The design has been worked out according to 802.11b lEEE standard.

KEYWORDS: Microstrip antenna, Feed point, Bandwidth, return loss.

1 Introduction

Microstrip antennas were first proposed in 1952. This concept had to wait until 1974 when that microstrip antenna got a lot of attention and began being used for military applications. So far, these antennas have mainly been used on aircraft, missiles, and rockets. Just recently, they have been expanded to commercial areas such as mobile satellite communication, the direct broadcast satellite (DBS), and the global position system (GPS) [1].With the wide spread proliferation of communication technology in recent years, the demand for compact, low profile and broadband antennas has increased significantly. A number of new developed techniques to support high data rate wireless communication for the next generation technologies have been rapidly increasing.

802.11b is one of many Institute of Electrical and Electronics Engineers (IEEE) standards that govern wireless networking transmission methods. They are commonly used today to provide wireless connectivity in the home, office and some commercial. It operates on a 2.4 GHz band and allows for wireless data transfers up to 11 Mbps. Several techniques have been proposed to enhance the bandwidth in the state-of-the art antenna research for microstrip patch antenna. In this research, our design is forwarded a rectangular shape that contains a single, double and triples U, concentered accordingly.

2 Design procedure

The basic design uses a rectangular U-slot microstrip patch antenna on suitable microwave substrates [1]. The new antenna is a probe-fed rectangular microstrip patch antenna on a permittivity substrate with an internal U- slot as shown in Figure 1. In the second design, Another U –slot is added, and the dimension of the second U-solt will be the half length of the first U-solt as shown in Figure 2. In the final design, a third U -slot is formed and its dimension will be the half length of the second U-solt see Figure 3.

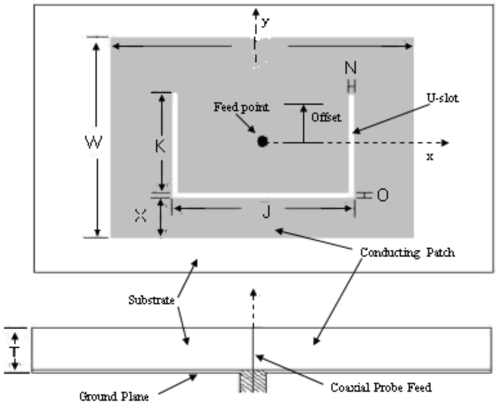


Figure 1: *Geometry of the rectangular U-slot microstrip patch antenna*

This design procedure is a set of steps for the rectangular U-slot mircostrip patch antenna. Specify the center frequency and 2:1 VSWR bandwidth of the desire antenna. Approximate the center frequency as (fres3) and the lower and upper frequency bounds of the bandwidth as (fres2) and (fres4) respectively. Select a substrate permittivity (ε_r) and a substrate thickness h. According to the following relationship [2]:

$$h \geq 0.06 \frac{\lambda_{res3}}{\sqrt{\varepsilon_r}} \tag{1}$$

where λ_{res3} wavelength at the center frequency in air.

Calculate the width of the patch W as:

$$W = \frac{c}{2.f_{r3}} \sqrt{\frac{2}{\varepsilon_r + 1}} \tag{2}$$

where c speed of light in free space.

Calculate the effective permittivity ε_{eff} as:

$$\varepsilon_{\mathrm{eff}} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(1+\frac{12h}{W}\right)^{-1/2} \tag{3}$$

Then the length due to the fringing field ΔL

$$\Delta L = 0.824h\frac{(\varepsilon_r+0.3)\left(\frac{W}{h}+0.262\right)}{(\varepsilon_r-0.258)\left(\frac{W}{h}+0.813\right)} \tag{4}$$

Calculate the length of the patch L as:

$$L = \frac{c}{2f_{r3}\sqrt{\varepsilon_{\mathrm{eff}}}} - 2\Delta_L \tag{5}$$

Select a starting value of slot thickness E,F using following:

$$E = F = \frac{\lambda_{\mathrm{res3}}}{60} \tag{6}$$

7) Calculate the Slot width J as:

$$J = \frac{c}{f_{r2}\sqrt{\varepsilon_{\mathrm{eff}}}} - 2(L + 2\Delta_L - E) \tag{7}$$

8) Select the Slot height K such that

$$\frac{K}{J} \geq 0.7 \text{ and } \frac{K}{W} \geq 0.3 \tag{8}$$

Calculate the effective permittivity and effective length extension of the pseudo patch $\varepsilon_{\mathrm{eff(pp)}}$ of the fourth resonance with the effective patch width $J - 2F$

$$\varepsilon_{\mathrm{eff(pp)}} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(1+\frac{12h}{J-2F}\right)^{-1/2} \tag{9}$$

$$2\Delta L_{L-E-H} = 0.824H\frac{\left(\varepsilon_{\mathrm{eff(pp)}}+0.3\right)\left(\frac{J-2F}{h}+0.262\right)}{\left(\varepsilon_{\mathrm{eff(pp)}}+0.258\right)\left(\frac{J-2F}{h}+0.813\right)} \tag{10}$$

Calculate the Height of slot from base H as:

$$H \approx L - E + 2\Delta_{L-E-H} - \frac{1}{\sqrt{\varepsilon_{\mathrm{eff(pp)}}}}\left(\frac{c}{f_{\mathrm{res4}}} - (2K + J)\right) \tag{11}$$

When The optimized lower band frequency, fres2= 1.8 GHz, upper bound frequency, fres4=3.1 GHz , Resonant Frequency fres3=2.45Ghz, εr = 4.2, and substrate Height = 10 mm are selected, The computed results are shown in Table 1 as:

Table 1: *Dimensions of single U slot antenna*

L (mm)	W (mm)	K (mm)	J (mm)	O (mm)	N (mm)	X (mm)	H (mm)	T (mm)	Offset (mm)	ε_r	f_3 (GHz)	f_2 (GHz)	f_4 (GHz)
24.7	37.9	13.4	28.1	2.0	2.0	10.0	7.6	10	0.0	4.2	2.45	1.8	3.1

The second design" the double U–slot patch microstrip antenna" is depended on the first design and the dimensions of the second U shape J', K' H' are the half length of first design. The next Table 2 summarizes the dimensions of the double U –slot patch microstrip antenna.

Table 2: *Dimensions of double U slot antenna*

L (mm)	W (mm)	K' (mm)	J' (mm)	O (mm)	N (mm)	X (mm)	H' (mm)	T (mm)	Offset (mm)	ε_r	f_3 (GHz)	f_2 (GHz)	f_4 (GHz)
24.7	37.9	6.7	14.05	2.0	2.0	10.0	3.8	10	0.0	4.2	2.45	1.8	3.1

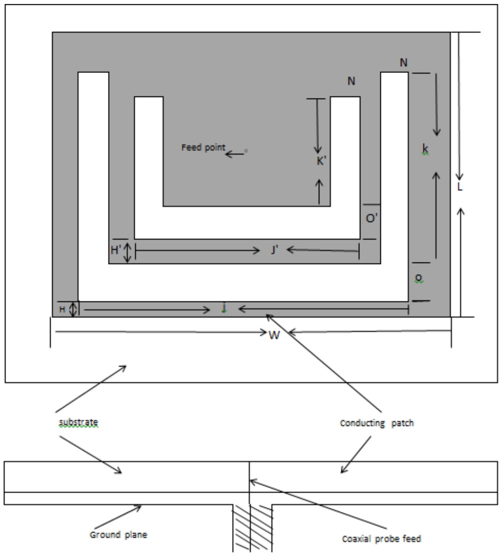


Figure 2: *Geometry of the rectangular double U-slot microstrip patch antenna*

In the same manner, the third design” the triple U–slot patch microstrip antenna “is depended on the second design and the dimensions of the third U shape J'', K'', H'' are the half length of second design. The next Table 3 summarizes the dimensions of the triple U –slot patch microstrip antenna.

Table 3: *Dimensions of triple U slot antenna*

L (mm)	W (mm)	K” (mm)	J” (mm)	O (mm)	N (mm)	X (mm)	H” (mm)	T (mm)	Offset (mm)	ε_r	f_3 (GHz)	f_2 (GHz)	f_4 (GHz)
24.7	37.9	3.35	7.02	2.0	2.0	10.0	1.9	10	0.0	4.2	2.45	1.8	3.1

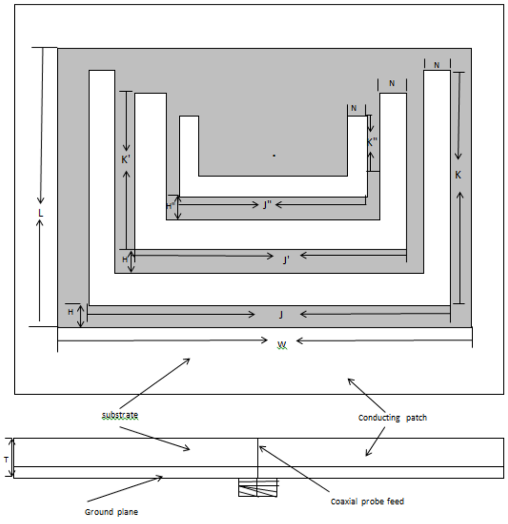


Figure 3: *Geometry of the rectangular triple U-slot microstrip patch antenna*

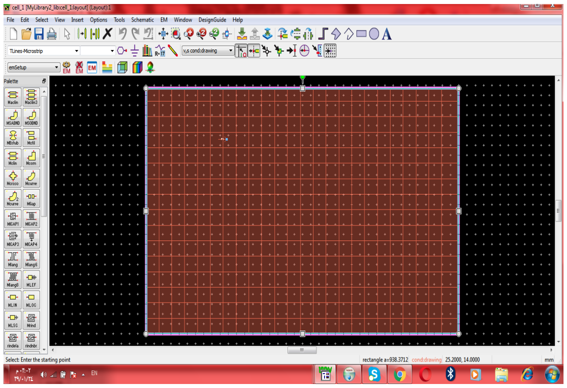
3 Result and discussion

3.1 Design of a rectangular patch microstrip antenna

Figure 4 illustrates a rectangle patch microstrip antenna which does not contain any slot in order to compare these results with the other designs to see how much improvement in the bandwidth. Figure 5 shows simulated results of the variation of return loss versus the frequency of the proposed antenna. There is a resonant frequency which is located at the desired values of 2.45 GHz with return loss of (-22) dB and 13% bandwidth. The Bandwidth (BW) % can be calculated as follow:

$$BW(\%) = \frac{f_h - f_l}{f_c} * 100 \tag{12}$$

Where f_h, f_l are the upper and lower frequency at the point -10dB, f_c is the resonant frequency .



Select: Enter the starting point

rectangle a=938.3712 cond:drawing 25.2000, 14.0000 mm

Figure 4: *Rectangular patch microstrip antenna*

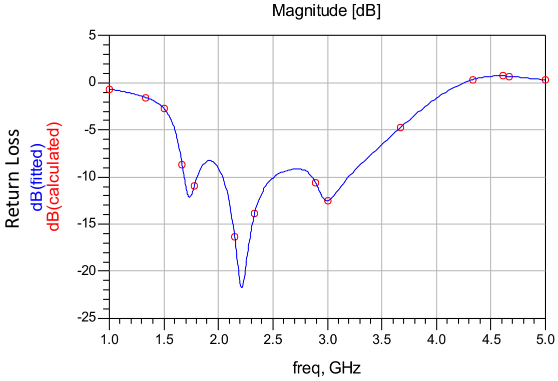


Figure 5: *Return loss of the rectangular patch microsrtip antenna*

3.2 Design of a rectangular U –slot patch microstrip antenna.

Figure 6 shows a rectangle U-slot patch microstrip antenna. Figure 7 shows the resonant frequency at 2.2 GHz with return loss of -21dB. In addition, a bandwidth of 51.36% was achieved.

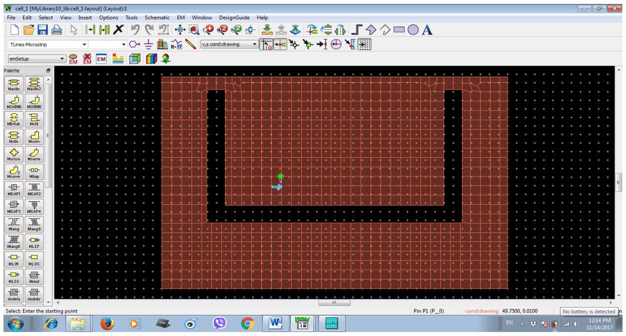


Figure 6: *Design of the rectangle U-slot patch micro strip antenna*

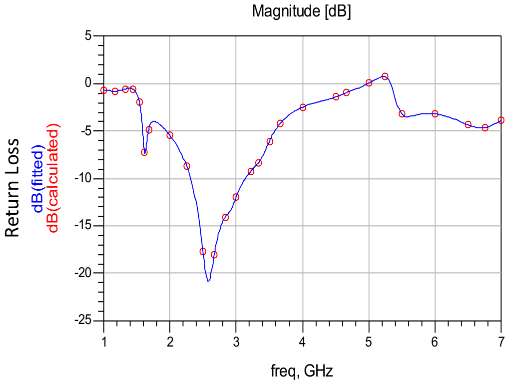
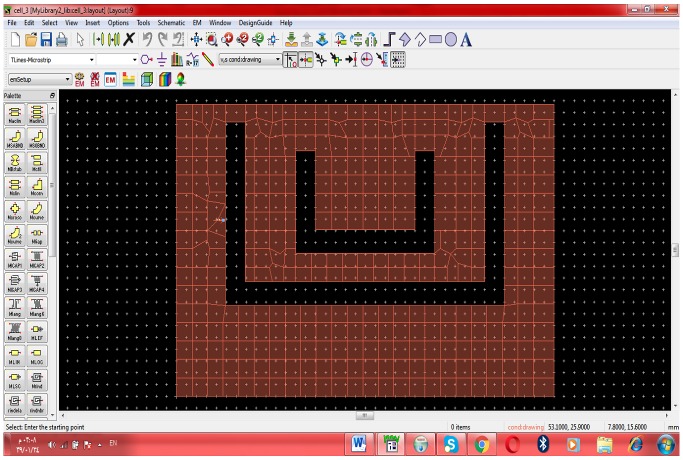


Figure 7: *Return loss of the rectangle U-slot patch micro strip antenna*

3.3 Design of a rectangular double U –slot patch microstrip antenna.

A rectangle double U-slot patch microstrip antenna is illustrated in Figure 8. From Figure 9, the antenna was found to be resonating at 2.47GHz with a return loss of -26 dB, and a bandwidth of 52.63% was achieved.



Select: Enter the starting point

0 items

cond:drawing 53.1000, 25.9000 7.8000, 15.6000 mm

Figure 8: *Design of the rectangle double U-slot patch microstrip antenna,*

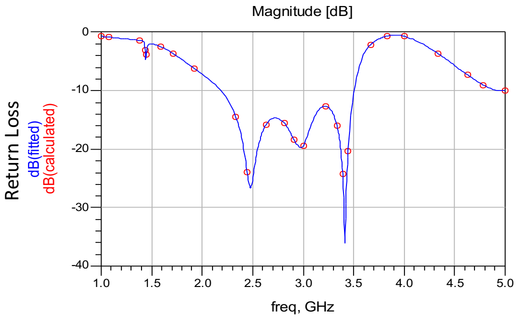


Figure 9: *Return loss of the rectangle double U-slot patch microstrip antenna,*

3.4 Design of a rectangular triple U –slot patch microstrip antenna.

Figure 10 shows a rectangle Triple U-slot patch microstrip antenna. Figure 11 shows a resonant frequency at 2.47GHz with a return loss of -22 dB. a bandwidth was found 52.63%, which is approximately the same as in a rectangle double U-slot patch microstrip antenna.

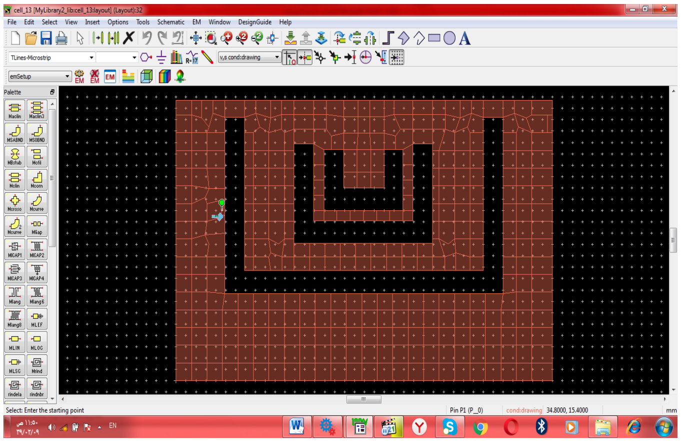


Figure 10: *Design of the rectangle triple U-slot patch microstrip antenna,*

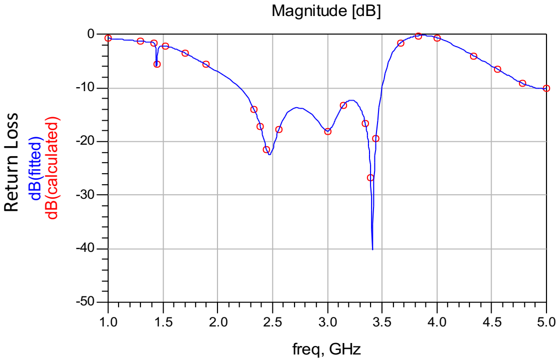


Figure 11: *return loss of the rectangle triple U-slot patch microstrip antenna,*

Table 4 summarizes the data from all designs. The three designs give bandwidth enhancement above 50%.The double U-solt and Triple U-slotpatch micro-strip give slightly higher bandwidth enhancement of 52.63% covering from 2.2 to 3.50 GHz frequency. It should be considered that the bandwidth specification changes according to the feed point location.

Table 4: *summarizes the data from all designs*

	$f_{c(GH_z)}$	$f_{u(GH_z)}$	$f_{l}(GH_{z})$	dB_i	Feed point position	bandwidth
Rectangular patch antenna	2.2	2.5	2.05	-26	(9.80,19.60)	13%
Single U-slot	2.2	3.13	2	-21	(7.60,20.00)	51.36%
Double U- slot	2.47	3.50	2.2	-26	(4.70,14.90)	52.63%
Triple U-slot	2.47	3.50	2.2	-22	(4.60,14.50)	52.63%

4 Conclusion

In this research, a rectangular shaped microstrip antenna has been designed that contains a single, double and triple U shape using ADS software. A single U shape has been designed and tested for the sake of increasing bandwidth at operating frequency 2.45 GHz. The achieved bandwidth was 51.36% at return loss equal to 21dBi. A double U shape microstrip antenna has also been tested with bandwidth equal to 52.63% at return loss equal to -26 dB. In addition, a triple U shape has also been undertaken to give bandwidth equal to 52.63% at return loss equal -22 dB. In general, the results are considered very satisfactory where most designs give bandwidth enhancements above 50% at very acceptable levels of return loss.

Reference

[1]. P. Bhattacharjee, V. Hanumante, S. Roy," Design of U-Slot Rectangular Patch Antenna for Wireless LAN at 2.45GHz", *9th International Conference on Microwaves, Antenna, Propagation and Remote Sensing*, 2013.

[2]. Aruna Rani, R.K. Dawre," Design and Analysis of Rectangular and U Slotted Patch for Satellite Communication", *International Journal of Computer Applications*, Volume 12– No.7, December 2010

[3]. Runa Rai, A. K. Gautam," improvement in gain and bandwidth of rectangular and U slot loaded patch", *International Journal of Computer Science Issues*, Vol. 8, Issue 6, No 2, November 2011

[4]. A. H. Khidre, Kai-Fong Lee, A. Z. Elsherbeni, F. Yang, "Wide Band Dual –Beam U-Slot Microstrip Antenna", *IEEE*, Vol. 61, No. 3, March 2013.

[5]. I. J. Bahl, P. Bhartia ," Design and Performance Evaluation of Microstrip Antenna for Ultra-Wideband Applications Using Microstrip Feed", *American Journal of Electrical and Electronic Engineering*, Vol. 3 No. 4, 93-99, 2015