Broadband Microstrip Patch Antenna for L-Band

Shweta Bhatnagar
Dehradun Institute of Technology
Dehradun (INDIA)
bhatnagarshweta11@gmail.com

Dr.S.C. Gupta
Dehradun Institute of Technology
Dehradun (INDIA)
sureshprem1938@gmail.com

Dr.Sandip Vijay
Dehradun Institute of Technology
Dehradun (INDIA)
vijaysandip@gmail.com

ABSTRACT- The broadband microstrip antenna is realized by cutting the slot of different shapes like U-slot, and pair of rectangular slots inside the patch. In this paper, a half U-slot and rectangular slots cut proximity fed broadband rectangular microstrip antenna is proposed. The analysis to study the effects of slot on the broadband response of slot cut patch is presented. Through the analysis it was observed that the slot modifies the resonance frequencies of higher order modes of the patch and yields broadband response. The bandwidth of more than 700 MHz (>56%) is obtained. The antenna gives broadside radiation pattern with a gain more than 6 dBi over the operating bandwidth.

Keywords- Proximity Feed, Half-U Slot, Rectangular Slot, Broadband Microstrip Antenna.

1. INTRODUCTION

The simpler method to realize broadband microstrip antenna (MSA) is by using thicker lower dielectric constant substrate [1, 2]. This substrate reduces the quality factor of the cavity below the patch and yields larger bandwidth (BW). However for substrate thickness in excess of 0.04λ0, the BW is limited by the feed probe inductance. By using simpler proximity feeding technique the BW is increased for substrate having thickness greater than 0.06λ0 [3]. Another more commonly used technique to realize broader BW is by cutting the slot of different shapes like, U-slot, Vslot and rectangular slot at an appropriate position inside the patch [4 – 8]. The slot is said to introduce a resonant mode near the fundamental resonance frequency of the patch and yields larger BW. While designing the slot cut MSA in the desired frequency band, the slot length is taken to be either half wave or quarter wave in length. However it was observed that this simpler approximation of slot length against the frequency does not give accurate results. The analysis to study the effects of U-slot on the broadband and dual band response in rectangular MSA (RMSA) is reported [9]. In that configuration three resonance frequencies were observed. The first frequency is due to the mode introduced by the U-slot wherein the total outer Uslot length equals half the wavelength. The second frequency was due to the patch TM01 mode. The third frequency was reported because of U-slot which equals TM20 frequency of the RMSA without the U-slot. Also, the plot of resonance frequencies obtained using proposed formulations against the simulated and measured results were not presented. The analysis to study the effects of slot on the broadband and dual band response of RMSA and circular MSA is carried out [10, 11]. The resonance curve plots, surface current distributions and the radiation pattern plots for different slot lengths were studied. It was observed that the slots does not introduce any additional mode but modifies the resonance frequency of higher order orthogonal mode of the patch and along with fundamental mode yields dual or broadband characteristics.

In this paper, a broadband proximity fed half U-slot and rectangular slot cut RMSA is proposed. To realize the broadband response the parametric study for variations in slot dimensions and the proximity feed location is carried out. The half U-slot and rectangular slots are cut such that they modify the resonance frequencies and the directions of the surface currents at higher order and orthogonal TM11 and TM01 modes resulting in broadband response. The BW of more than 700 MHz (>56%) is obtained. The radiation pattern is in the broadside direction with gain of more than 6 dBi over the VSWR BW. Since the orthogonal higher order modes are present towards the lower and higher frequencies of the BW, the cross-polarization levels are higher. To realize maximum radiation efficiency the proposed antenna is optimized using an air substrate and it is fed using the 0.3cm inner wire diameter. The antenna is first optimized using the HFSS software [12]. In the simulation an infinite ground plane is used. To simulate this effect in the measurements a larger square ground plane of side length 50 cm is used [1]. In measurements the antenna is fabricated using the copper plate and it is supported in air using the foam spacer placed towards the antenna corners. The foam spacers have dielectric constant of very close to unity therefore it does not alter the effective dielectric constant of the proposed configuration. The radiation pattern over the BW is measured in minimum reflection surroundings with required minimum far field distance between the reference antenna and the antenna under test [13]. The antenna gain is measured using the three antenna method [13].

2. PROXIMITY FED RMSA

An The proximity fed RMSA is shown in Fig. 1-2. To realize larger gain a higher substrate thickness of 2.8 cm is selected (0.09λ0). The patch length is selected such that it resonates in the TM10 mode at frequency of around 950 MHz. The patch length was found to be 13 cm. To realize closely

ISSN 2229-5518

spaced orthogonal frequencies, the patch width is taken to be nearly equal to the patch length. Hence the patch width is taken to be 12 cm. The coupling rectangular strip is placed below the patch at substrate thickness of 2.8 cm (0.084λ0). This proximity fed MSA is simulated using HFSS software and the frequency versus Return loss curve plot for the same is shown in Fig. 3. The gain of the RMSA shown in Fig. 4.

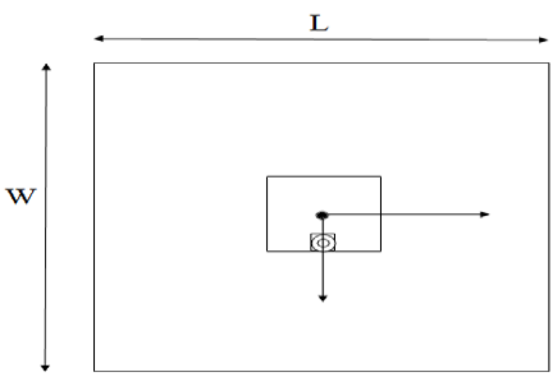

Fig.1: Schematic design of figure.

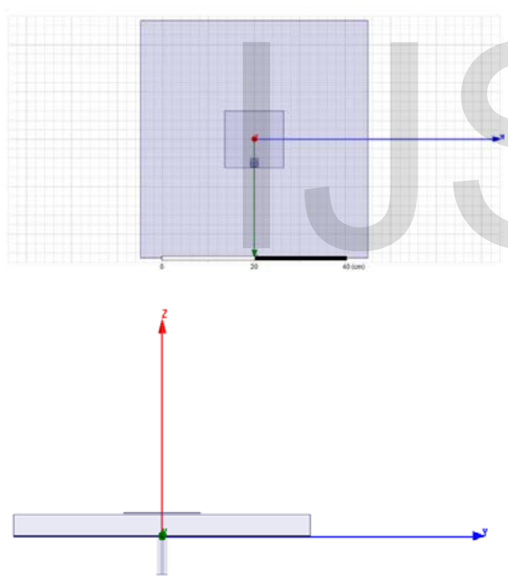

Fig. 2 Top and side view of proximity fed RMSA

Operating frequency for this patch is 1-2 GHz. f_L= .960 GHz and f_H= 1.160 GHz. Bandwidth obtained here is 18.85% with gain of 9.12 dB where BW is very narrow. Frequency versus return-loss and gain graphs is shown in Figure 3-4 below:

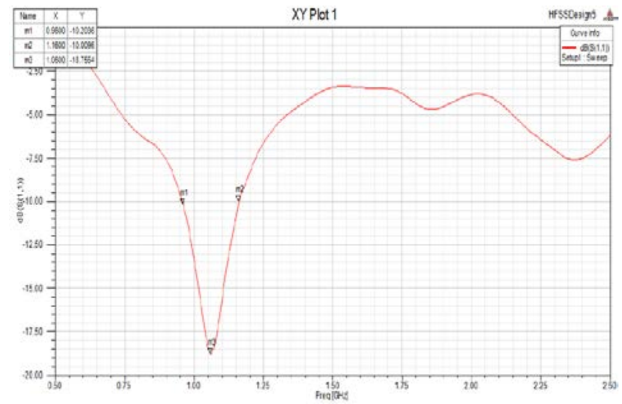

Fig 3: Frequency versus return-loss graphs

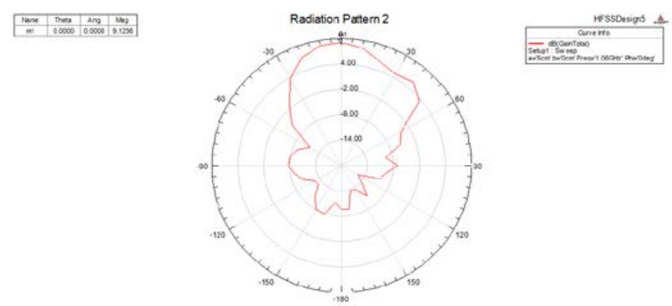

Fig 4: Frequency versus gain graphs

3. PROXIMITY FED SLOT CUT RMSAs

Inside this patch, half U-slot are cut to realize broader BW. The broadband proximity fed half U-slot is shown in Fig.5. The half U-slot is cut on the length of the patch. While optimizing for broader BW, first a half U-slot is cut and the frequency versus return loss curve plot for the varying half U-slot length is shown in Fig. 6. The slot length is parallel to the surface currents at TM10 mode therefore decrease in its frequency is negligible. However the slot length is orthogonal to the surface currents at TM01 mode and therefore its frequency reduces and for larger slot length, a separate peaks due to the two modes (i.e. TM10 and TM01) starts appearing in the return loss curve plots. The resonance frequency also reduces with the increasing half U-slot length. The realized simulated BW is nearly 291 MHz. However as the modified higher order orthogonal modes are present the surface currents in the patch are directed along the patch length and the width. This leads to radiation pattern with higher cross-polarization levels with variations in the directions of E and H-planes over the BW.

ISSN 2229-5518

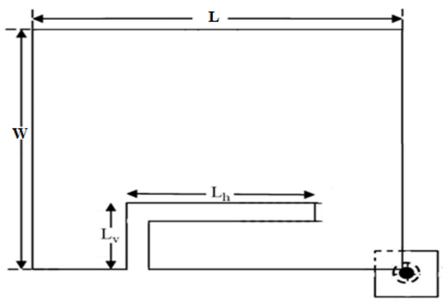

Fig 5: Schematic design of figure.

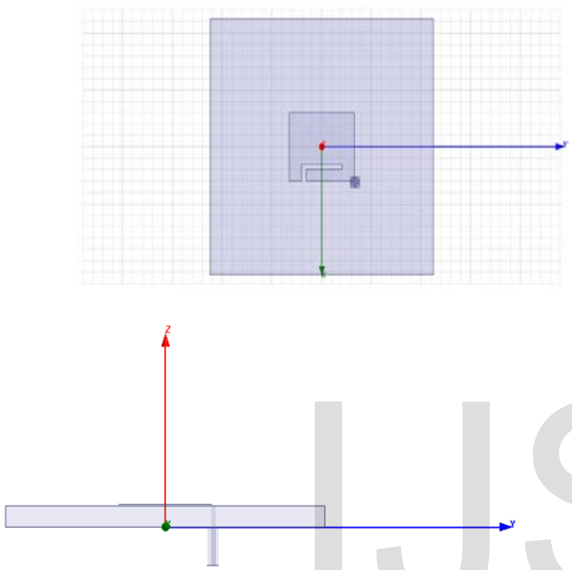

Fig 6: Top and side view of half U-shaped patch antenna.

Dimension of patch are given below:

L= 13 cm

W= 12 cm

Position of feed point along y-axis = 6.7 cm

Two slots one of width 1 cm and length of 8.2 cm are cut, 2.4 cm apart from Left corner. Another one is of width 1cm and length of 3 cm are cut, 9.6 cm apart from Right corner.

Slot width (P) $\cong \frac{W}{10} \cong$ after optimization = 1 cm

Slot Length (L_h) $\cong 0.27\lambda \cong 0.27 X 30.3 = 8.2$ cm; (where λ= 30.33 cm)

L_v= 3cm $\cong 0.0954\ \lambda$

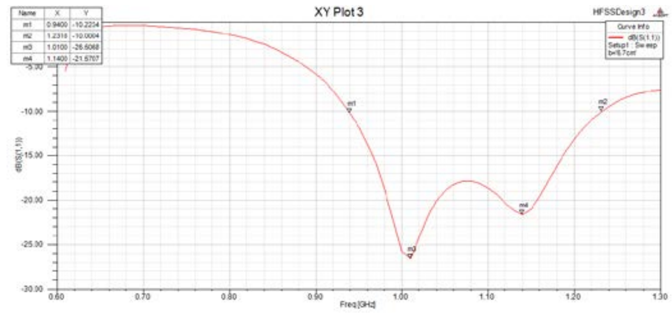

Fig 7: Frequency versus return-loss graph

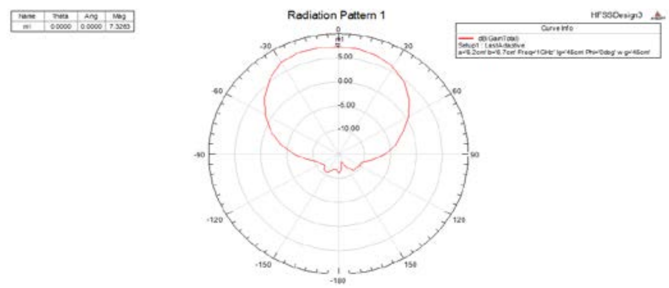

Fig 8: Frequency versus gain graphs.

The broadband proximity fed half U-slot and a rectangular slots cut RMSA is shown in Fig. 9 To optimize and broaden the bandwidth , a additional pair of rectangular slots were cut along the edges of the patch as shown in Fig. 9. The rectangular slot dimensions (Lh1, Lv1, Lh2 and Lv2) are optimized such that they will modify the surface current distributions on the patch. The rectangular slot mode, the surface current shows a half-wavelength variation along the total slot length

(2*slot length+ width) ….(1)

with the current maximum toward the shorted end of the slot [11], [12]. First the slot length Lh1 is varied and then the slot width Lv2 is optimized. With an increase in Lv1 the effective patch dimensions are reduced which decreases the resonance frequency of TM10 and TM11 modes. Further with an increase in Lv2, the TM10 mode frequency nearly remains constant whereas the TM11 mode frequency reduces. These additional slots also help in increseing the bandwith. The optimum broadband response is obtained for slot dimensions of Lv1 = 5.5 cm, Lh1 = 1.5 cm and Lv2 = 2.0 cm and Lh2 = 1.0 cm . Now optimise half-U-slot. After calculating the required half-U-slot length, the horizontal half-U-slot length is taken to be greater than the vertical half-U-slot length (Lh > Lv), as larger vertical length affects the resonance frequency of the patch as well as the impedance variation along the patch length. The half-U-slot frequency also depends upon the ratio of horizontal to vertical slot length [12].

$$Lh - w + Lv = \lambda/4 \quad \ldots(2)$$

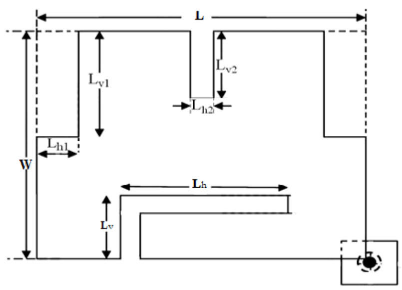

Fig.9: Schematic design of figure 10.

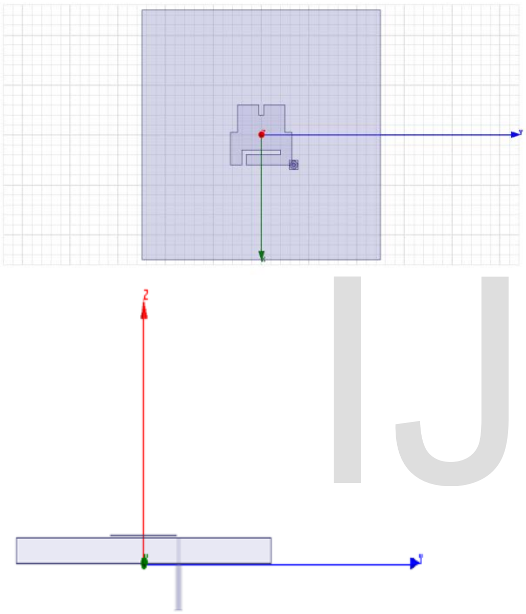

Fig 10: Top and side view of proximity feed half U-slot and pair of rectangular slots cut RMSA

Dimensions are:

Dielectric constant = 1.01 (air)

h = 2.8cm (0.08 λ)

Wg=28.8cm, Lg=29.8cm

Lh=8.2cm, Lv=3cm (0.27λ and 0.0954λ resp.)

Slot width (P) $\cong \frac{W}{10} \cong$ after optimization = 1 cm

Lv1=5.5cm, Lh1=1.5cm (0.185 λ and 0.056 λ resp.)

All these dimensions are optimized to obtain better results.

Dimensions are same to that of antenna 1 and antenna 2. Here position of feed point is optimized to get the best result in terms of bandwidth and gain. After optimization position of feed point is 6 cm away from center point towards –ve y-axis.

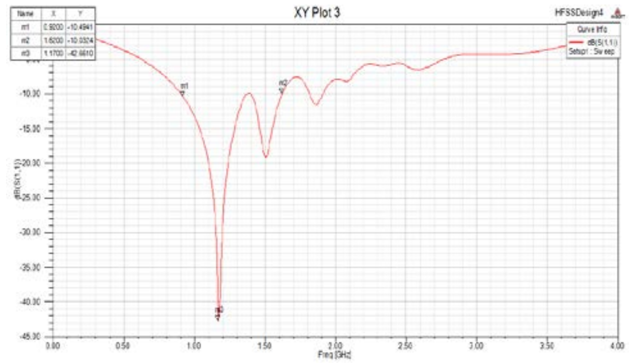

Fig 10 : Frequency versus return-loss

Lower frequency f_L=.920GHz and higher frequency f_H=1.62GHz, bandwidth obtained 700 MHz which is 55.11 % with centre frequency f_0=1.27GHz and gain of more than 6dB having return loss of -42.66dB .

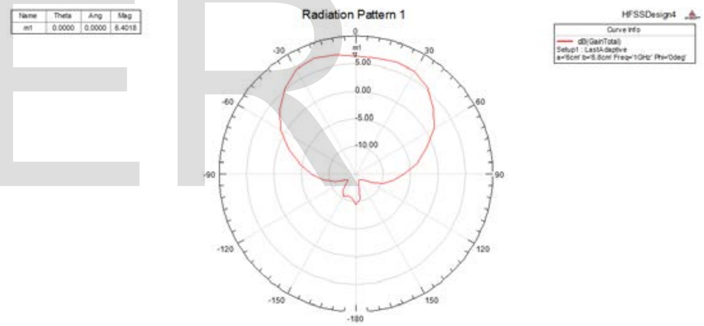

Fig 11: Frequency versus gain graphs.

1.1 COMPARATIVE ANALYSES

S. No.	Design configuration	f_L (GHz)	f_H (GHz)	f_0 (GHz)	% age and impedance Bandwidth	Gain (dB)
1.	Rectangular Patch Antenna	.960	1.160	1.06	18.88% 200MHz	9.12 dB
2.	Half-U-Shaped Patch Microstrip Antenna	.940	1.231	1.08	27%	7.32 dB

					291MHz	
3.	Half - U-slot and pair of rectangular slots cut RMSA	.920	1.620	1.27	55.11% 700 MHz	6.40 B

4. CONCLUSION AND FUTURE SCOPE

Different Shape of microstrip patch antenna configurations i.e. half-u slot RMSA and pair of rectangular MSA and Half-u slot RMSA configurations are designed to obtain wideband characteristic at frequency bands i.e. L-band. We have edge cut half-u slot beacause it radiates at L-band frequency. Half-u slot cut RMSA configuration with patch which yields the bandwidth of 27 % at center-frequency 1.08GHz with high gain of 7.32dB.

The rectangular and half-u slot RMSA configuration which yields the wideband of 55.11% at center-frequency 1.27GHz with high gain of 6.41dB and return loss of 42.66 dB . with proximity coupled feed the maximum bandwidth achieved is found to be 45% and in this thesis the bandwidth achieved is 55.11%.

This bandwidth could be further enhanced by different broadband enhancement techniques for Half U-shaped patch and RMSA.

5. REFERENCES:

[1] R. Garg, P. Bhartia, I. Bahl and A. Ittipiboon, "Microstrip Antenna Design Handbook", Artech House, USA, 2001.

[2] B. Bhartia and I. J. Bahl, Microstrip Antennas, USA, 1980

[3] G. Kumar and K. P. Ray, Broadband Microstrip Antennas, First Edition, USA, Artech House, 2003.

[4] T. Huynh and K. F. Lee, "Single-Layer Single-Patch Wideband Microstrip Antenna," Electronics Letters, vol. 31, no. 16, August 1995, pp. 1310-1312.

[5] R. Chair, K. F. Lee, C. L. Mak, K. M. Luk and A. A. Kishk, "Miniature Wideband Half U-Slot And Half E Patch Antennas," IEEE Transactions on Antenna And Propagations, vol. 52, no. 8, August 2005, pp. 2645-2652.

[6] A. A. Deshmukh and G. Kumar, "Broadband pairs of slots loaded Rectangular Microstrip antennas", Microwave and Optical Technology Letters, vol. 47, no. 3, 5th Nov. 2005, pp. 223 – 226.

[7] A. A. Deshmukh and G. Kumar, "Compact Broadband U-slot loaded Rectangular Microstrip Antennas", Microwave & Opti. Tech. Letters, vol. 46, no. 6, 2005, pp. 556 – 559

[8] A. A. Deshmukh and G. Kumar, "Various slot loaded Broadband and Compact Circular Microstrip Antennas", Microwave and Optical Technology Letters, vol. 48, no. 3, Mar. 2006, pp. 435 – 439.

[9] K. L. Wong and W. H. Hsu, "A broadband rectangular patch antenna with a pair of wide slits", IEEE Trans. Antennas Propagat., vol. 49, Sept. 2001, pp. 1345 – 1347

[10] K. L. Lau, S. H. Wong and K. M. Luk, "Wideband Folded feed L-slot folded patch antenna", IEEE Antennas & Wireless Propagation Letters, vol. 8, 2009, pp. 340 – 343.

[11] A. A. Deshmukh and G. Kumar, "Compact broadband E-shaped microstrip antennas," Electron. Lett., vol. 41, no. 18, pp. 989–990, Sept. 1, 2005.

[12] Ansoft High Frequency Structure Simulator, "Proximity Feed Patch Antenna", v10 User's Guide, 2005.

[13] A. A. Deshmukh and G.Kumar, "Even mode multi-port network model for slotted dual band rectangular microstrip antennas," Microw. Opt. Technol. Lett., vol. 48, no. 4, pp. 798–804, Apr. 2006.

[14] Sana R Vhora , M.D. Amipara, "A Novel Design of Rectangular Patch Antenna for Broadband Applications," International Journal of Engineering Research & Technology (IJERT) Vol. 2 Issue 1, January- 2013, pp. 1-4.