ISSN (Online) : 2278-1021
ISSN (Print) : 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 3, Issue 4, April 2014

Design And Enhancement of Gain & Bandwidth Of Rectangular Patch Antenna Using Shifted Semi-Circular Slot Technique

Pampa Debnath[1], Sohini Pal[2], Amrita Maity[3], Riya Bhattacharyya[4], Krishna Mahato[5]

Assistant Professor, Department of Electronics & Communication Engineering, RCCIIT, Kolkata, India [1]

Student, Department of Electronics & Communication Engineering, RCCIIT, Kolkata, India[2,3,4,5]

Abstract: Microstrip Antennas are strongly used in wireless communication applications. This paper proposed a rectangular patch antenna loaded with a semi-circular slot to operate at 5.25 GHz with moderate gain (about 8.53dBi), bandwidth (96.7 MHz) and a good matching(S_{11}=-24.13dB).This paper also describes the increment in Bandwidth and Gain of Rectangular Microstrip Patch antenna with the Slot. Microstrip patch antenna is designed on a Duroid 5880 substrate with a dielectric constant of 2.2. The results of both the designs with and without slots are compared and it was found that an increase in the bandwidth by33.82% and gain by 28.25% are being achieved. The antenna is designed based on extensive HFSS simulation studies.

Keywords: Bandwidth, Gain, Rectangular microstrip patch antenna, Shifted Semi-Circular Slot, rectangular microstrip patch antenna, HFSS, Matlab.

I. INTRODUCTION

Microstrip antennas fulfill most of the wireless requirements[1],[2],[3],[6]. They are lightweight, small in size, simple to manufacture, cost effective, reliable and have a varied range of configurations. These antennas have increasingly wide range of applications in space technology, aircrafts, missiles, mobile communications, GPS system and broadcasting. However these antennas suffer from low gain and narrow bandwidth. There are various methods to improve the bandwidth and gain, such as using various impedance matching and feeding techniques, utilization of thick substrates with low dielectric constant, etching slot in the radiating patch[7],[8]. Among all these alternatives the slotted patch is an easy and efficient technique.

II. RECTANGULAR MICROSTRIP PATCH ANTENNA DESIGN

Simply, microstrip structure consists of a thin sheet of low-loss insulating material called the dielectric substrate. It is completely covered with a metal on one side, called the ground plane, and partly metalized on the other side where the circuit or antenna patterns are printed. Here the antenna is designed on a Duroid 5880 substrate with a dielectric constant of 2.2. The antenna is fed by a Coaxial probe feed. Designing of microstrip patch antenna depends upon three parameters. In this paper, selected three parameters are: Resonant Frequency (f_0) = 5 GHz, Dielectric constant (ε_r) = 2.2, Height of the dielectric substrate (h) =0.787 mm. Using MATLAB all dimensions have been calculated and finally verified by HFSS

A. Calculation of the Width (w):

$$w = \frac{c}{2f_0}\sqrt{\frac{2}{\varepsilon_r+1}} \quad (1)$$

(where c is the velocity of light)

which comes out to be **23.71 mm**.

B. Calculation of Effectivedielectric constant (ε_{reff}):

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(1+12\frac{h}{w}\right)^{-\frac{1}{2}} \quad (2)$$

which comes out to be **2.107**

C. Calculation of the Effective length (L_{eff}):

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{reff}}} \quad (3)$$

which comes out to be **20.66 mm**

D. Calculation of the Length Extension(ΔL):

$$\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.3)\left(\frac{w}{h}+0.264\right)}{(\varepsilon_{reff}-0.258)\left(\frac{w}{h}+0.8\right)} \quad (4)$$

which comes out to be **0.41 mm**.

E. Calculation of actual length of patch (L):

$$L = L_{eff} - 2\Delta L \quad (5)$$

which comes out to be **19.84 mm**.

Table I
Microstrip Patch Antenna parameters

Parameter	Dimension
Operating/Resonant Frequency (f_0)	5 GHz
Dielectric Constant (ε_r)	2.2
Height of substrate(h)	0.787 mm
Length(L)	19.84 mm
Width(w)	23.71mm

ISSN (Online) : 2278-1021
ISSN (Print) : 2319-5940
International Journal of Advanced Research in Computer and Communication Engineering
Vol. 3, Issue 4, April 2014

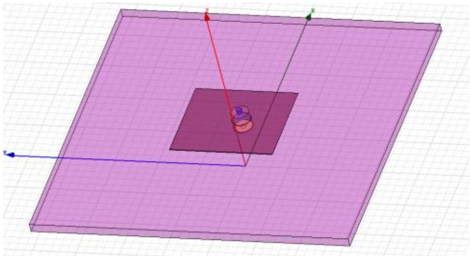


Fig 1.Rectangular Patch Antenna model

III. DETERMINATION OF PROBE FEED POSITION (PC,PY)

At the proper feed point location the input impedance is nearly 50 ohm and hence the antenna will be properly matched which is necessary for an acceptable bandwidth. Here, trial and error method is used to determine the appropriate location.

Table II
Probe feed location

Feed position(pc, py) mm,mm	Return Loss (S_{11}) dB	Gain dB	Bandwidth MHz	Resonant frequency GHz
3.9,0	**-26.66**	**6.12**	**64**	**4.55**
3.95,0	-24.93	8.06	58	4.38
3,1.2	-13.53	8.286	42	4.57
3.2, 1	-17.08	8.201	57	4.6
3.5,2.4	-23.93	8.3	62	4.57
3.8,0.5	-17.58	8.14	49	4.44

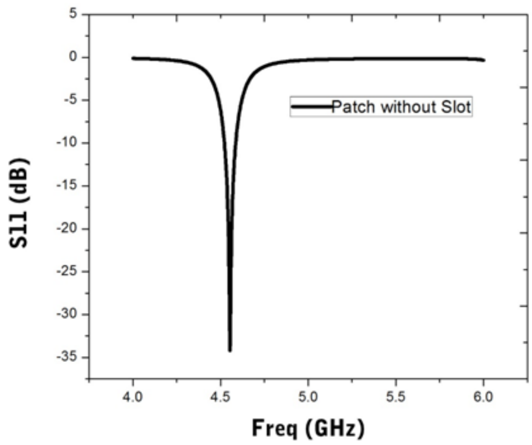


Fig 2. Return loss curve

Bandwidth of the antenna is defined as the range of frequencies, over which the performance of the antenna with respect to some characteristic conforms to a specific standard. The bandwidth of the antenna depends on the patch shape, resonant frequency, dielectric constant and the thickness of the substrate. The bandwidth enhancement of a microstrip antenna has been directed towards improving the impedance bandwidth of the antenna element. Impedance bandwidth is usually specified in terms of a return loss.

From TABLE II, it is found the best impedance matching occurred at feed point location (3.9, 0).The minimum return loss available is (-26.66 dB) at resonant frequency 4.55 GHz which is significant. At this feed location calculated bandwidth is 64MHz.Gain vs. theta plot at the operating frequency of 4.55GHz for rectangular microstrip patch antenna is given in Fig. 3 which gives the gain of 6.12 dBi.

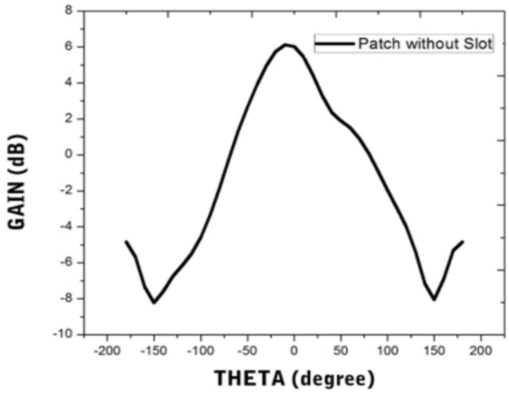


Fig 3. Gain vs. Theta curve at 4.55 GHz

IV. SHIFTED SEMI-CIRCULAR SLOT RECTANGULAR MICRSTRIP PATCH ANTENNA DESIGN

The poor bandwidth of the patch antenna is partly due to its scattering field. The total scattering field of antennas constitutes structural scattering and antenna-mode scattering. The source of structural scattering field of microstrip antenna is the inducing current[1],[2]. The techniques of slot-cutting can change the radiation and impedance property of microstrip antenna, which has been used in this paper to improve the bandwidth of antenna. Considering the radiation and scattering property, we designed the patch with a Semi-circular slot positioned at the centre of the Rectangular microstrip patch. The novel shape of patch-slot has changed the direction of the inducing current, so the scattering field counteract because of the different phase. The structural scattering field of microstrip antenna is reduced thereby increasing the bandwidth [9].

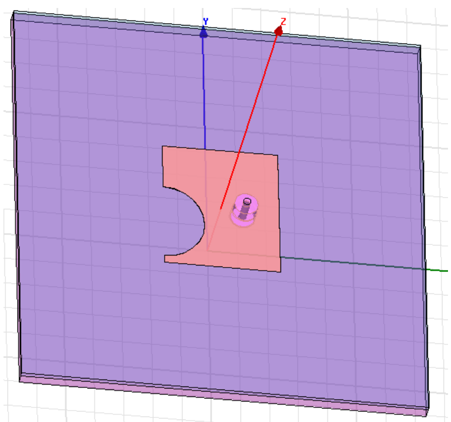


Fig 4.Rectangular Microstrip Patch antenna with the Shifted Semi-circular Slot

ISSN (Online) : 2278-1021
ISSN (Print) : 2319-5940
International Journal of Advanced Research in Computer and Communication Engineering
Vol. 3, Issue 4, April 2014

We then successively varied the **radius of the slot(cr),**the **slot position(cp)** and finally the **feed location(pc,py)**by trial and error to obtain the optimum value of bandwidth and gain. The results are given in **Tables III, IV** and **V** respectively.

Table III
Keeping slot position (cp) fixed at -3.45mm, pc=3.9mm,py=2.4mm and changing the slot radius(cr)

Feed position (pc,py) mm,mm	- S_{11}(dB)	Gain dB	Bandwidth MHz	Resonant freq (GHz)
4, 0	15.17	8.47	53.5	4.87
4.5, 0	53.38	8.25	75	4.91
4.5, 2.5	14.49	7.97	85.2	5.26
4.5, 1	25.77	8.32	78	4.87
3.9,2.4	**24.13**	**8.53**	**96.7**	**5.25**
3.95, 2.4	23.23	7.99	94.7	5.25

Table IV
Keeping slot radius (cr) fixed at 7mm, pc=3.9mm,py=2.4mm and changing the slot position(cp)

Slot radius(cr) mm	-S_{11} (dB)	Gain (dB)	Bandwidth MHz	Resonant freq (GHz)
1.5	18.28	8.06	75.6	4.69
2.5	20.04	8.57	81.5	4.80
3.5	22.21	8.07	79.1	4.84
4.5	22.16	8.93	89.9	4.94
4.8	26.30	9.12	91.9	4.96
5	24.81	8.88	87.6	5
6	26.43	8.17	95.1	5.12
7	**25.63**	**8.24**	**96.0**	**5.25**
8	21.25	8.01	93.6	5.37

Table V.
Keeping slot radius(cr) fixed at 7mm, slot position(cp)=-2.8 changing probe position pc,py

Slot position (cp) mm	-S_{11} (dB)	Gain (dB)	Bandwidth MHz	Resonant freq (GHz)
1.3	20.11	8.36	75.5	5.18
-2.1	28.85	8.71	94.4	5.21
-2.2	27.24	8.45	91.8	5.22
-2.4	25.78	8.58	93.1	5.22
-2.6	25.63	8.63	93.2	5.24
-2.8	**24.13**	**8.53**	**96.7**	**5.25**
-3.2	25.78	8.58	95.8	5.25
-3.4	23.26	8.57	94.5	5.26
-3	24.14	8.06	90	5.25
-2.5	25.79	8.51	96.3	5.23

V. RESULTS AND DISCUSSION

From Table V it is found that the most appropriate values are:

slot radius (cr)= 7mm
slot position(cp)= -2.8mm
probe position(pc,py)= 3.9mm, 2.4mm

which gives the maximum bandwidth of **96.7MHz**, which is **33.82%** more than the Rectangular Microstrip Antenna. The gain **(8.53dBi)** has also improved by **28.25%.**Figures 5 and 6 show the performance curves of the slotted patch antenna. The improved bandwidth and gain are shown in fig. 7.

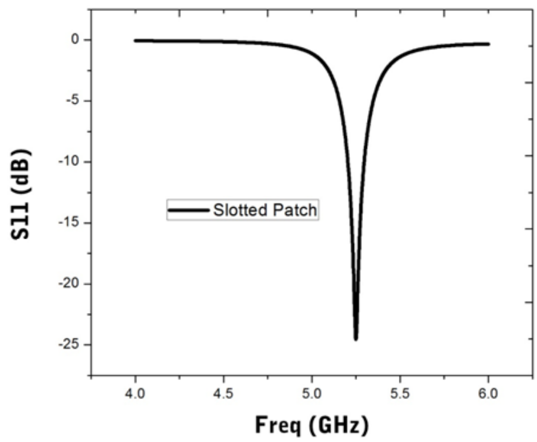


Fig 5. Return Loss curve of the Slotted Patch

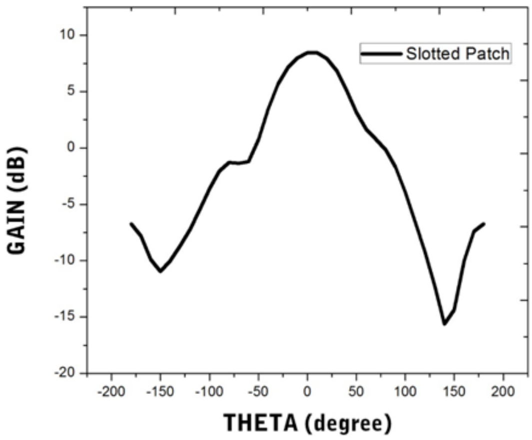
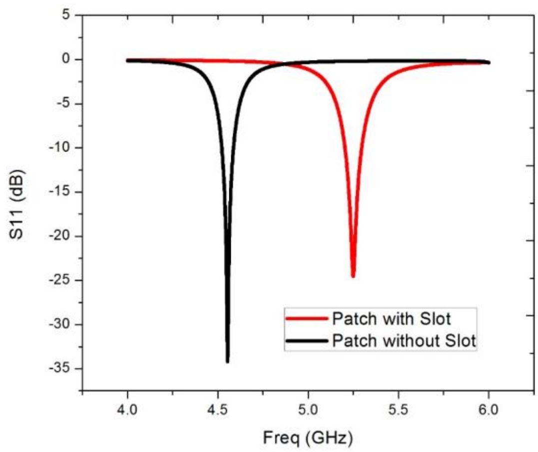


Fig 6. Gain vs. Theta curve of the Slotted Patch at the operating frequency of 5.25 GHz



ISSN (Online) : 2278-1021
ISSN (Print) : 2319-5940

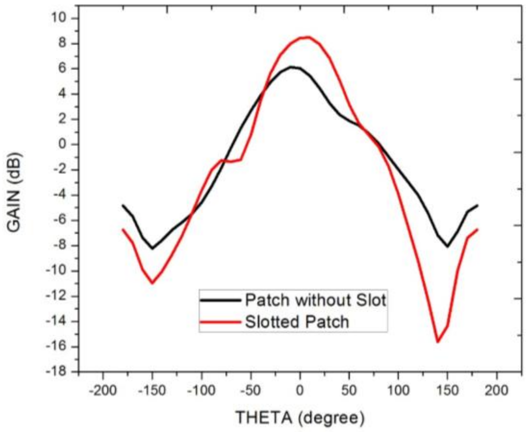


Fig 7. Comparison of Return Loss & Gain Curves

VI. APPLICATION

The proposed antenna design in this paper operates at the frequency of 5.25GHz and has the bandwidth of 96.7MHz (5.2011GHz - 5.2971GHz). It can be used in WLAN applications (IEEE 802.11ac standard).The IEEE 802.11ac is a standard under development which will provide high throughput in the 5 GHz band.

VII. CONCLUSION

The rectangular patch antenna with and without a shifted semi-circular slot are analyzed. Both the feed probe positions and the slot positions are varied to achieve an optimum bandwidth and gain. The Shifted slot increased the bandwidth by33.82% and more gain is obtained i.e. 8.53dBi.The antenna model also provides good matching with return loss (S_{11}= -24.13dB).

REFERENCES

[1] C. A. Balanis, “Antenna Theory, Analysis and Design”, 3rd edition, John Wiley & Sons
[2] J.D. Kraus, “Antennas for All Applications”, 3rd edition, TMH.
[3] D. M. Pozar and D. H. Schauberted, Microstrip Antennas, New York, IEEE Press.
[4] Sohini Pal, Pampa Debnath, “Bandwidth enhancement of Rectangu;ar Patch using Semicircular slot technique”, TNSCMPLA 2013,pp 40.
[5] Isha Puri, Archana Agarwal, “Bandwidth and Gain Increment of Microstrip Patch Antenna with Shifted Elliptical Slot”, IJEST, Vol. 3 No. 7 July 2011.
[6] Adit Kurniawan, Iskandar & P.H. Mukti, “A 2.3/3.3 GHz Dual Band Antenna Design for WiMax Applications”, ITBJ. ICT, Vol. 4, No. 2, 2011, 67-78.
[7] N. Herscovici, “New considerations in the design of microstrip antennas.” IEEE Transactions on Antennas and Propagation, AP-46, 6, June 1998, pp. 807-812.
[8] Sanjeev Kumar Sharma and Munish Rattan, “Analysis of Broadbanding and Minimization Techniques for Square Patch Antenna” March 25, 2011.
[9] Y. Li, Y. Liu, and S. Gong “Microstrip Antenna using ground cut slots for low RCS with size Miniaturization Techniques” Progress In Electromagnetics Research Letters, Vol. 1, 211–220, 2008.