Notch To Radiating Edge With Novel Loading Of Capacitance To Wideband Microstrip Patch Antenna

Ahire Dnyaneshwar, KharateGajanan

Abstract: Capacitive loading to radiating edge notch cut slot loaded microstrip patch antenna for biomedical applicationsis presented. I-shaped slot is introduced on radiating patch to match impedance. Notch on diagonal sides of patch is introduced to achieve wide bandwidth of 2.16GHz from 4.74GHz to 6.9GHz. Innovative idea of capacitive loading is presented to improve gain. The antenna is simulated using FR4 substrate with size of 0.215λ0×0.298λ0. Impedance Bandwidth of 2.16GHz. Parametric analysis of notch cut slots is presented. The proposed antenna has been simulated using CADFEKO simulator.

Index Terms: CapacitiveLoad, FCC, I- slot, Notch Cut, UWB.

1. INTRODUCTION

Capacitive loading to radiating patch is used to enhance Bandwidth and Gain. The main objective of this research work is to discuss the use and effects of capacitive loading technique. Recent requirement of wireless communication devices used in commercial, defense as well biomedical application is of wide bandwidth, and integrated in system. In this paper, capacitive loaded, I-shape slotted, notch cut probe feed wideband microstrip patch is design. Designed structure achieves 2.16GHz bandwidth with moderate gain. These structure full fill Ultra-Wide Band(UWB) bandwidth criteria define by Federal Communications Commission (FCC). Author presents slotting method, useful to convert single band antenna to multiband operation. T-slot with capacitive loading technique enhances bandwidth as well gain.Defective ground structure introduced to match impedance (Chakraborty U., Kundu A., Chowdhury K., and Bhattacharjee A. K 2014). Designed structure resonates in ISM and C band. Authors proposed U-slot antenna for multiband operation.Cutting of slot on radiating patch is used to operate implemented structure in multi resonate frequencies (Zhang Y.P 2007). Designed antenna -10db impedancebandwidth is begins at 2.474GHz and is up to 2.691GHz second band is begins at 4.313GHz it is up to 4.359GHz. Research group (Ansari J. A., Ram R.B., 2008, Deshmukh A.A., and Ray K.P, 2009) presents slot cutting microstrip patch antenna loaded with metamaterial to enhance performance. Researchers have been presented multiband microstrip patch antenna loaded with slot. Also presents analysis of design configuration. Research groups have been discussed broadband microstrip patch antenna resonates for more than one frequencies.

- *AhireDnyaneshwar ,Department of Electronics and Telecommunication, MatoshriCollege of Engineering and Research Centre, Savitribai PhulePune University Nasik, (MS) India; Email: dda007132@gmail.com*
- *Kharate Gajanan, Department of Electronics and Telecommunication, Matoshri College of Engineering and Research Centre, Savitribai Phule Pune University Nasik, (MS) India; Email: gkkharate@rediffmail.comb*

Author presents slotting method, useful to convert single band antenna to multiband operation. T-slot with capacitive loading technique enhances bandwidth as well gain (Ahire Dnyaneshwar, Kharate Gajanan 2016). Defective ground structure introduced to match impedance. Designed structure resonates in ISM and C band. Authors proposed U-slot antenna for multiband operation. Cutting of slot on radiating patch is used to operate implemented structure in multi resonate frequencies (Ahire Dnyaneshwar, Bhirud S.R. 2015). Designed antenna resonates at two bands with -10db impedance bandwidth is of 218MHz and 46MHz respectively. Research group present (Joshi J.G., Pattnaik Shyam S., and Devi S. 2013 presents slot cutting microstrip patch antenna loaded with metamaterial to enhance performance. Authors proposed different techniques of enhancement of bandwidth and gain. Discuss on miniaturization of microstrip patch antenna. Different kind of slots like L Shape U shape and wide slits have been used to enhance performance. This paper is planned as follows. Section II provides design of I slotted capacitive loading microstrip patch antenna. Section III gives detail parametric study Section IV and section V gives results and conclusion respectively.

2.RECTANGULAR MICROSTRIP PATCH ANTENNA DESIGN

First structure (Antenna 1) is of reference antenna design for 2.45GHz using approximate transmission line methodology. The FR4 substrate with dimensions W=6h+W and L=6h+L and thickness is of 1.59mm. Coaxial at $X_f = \frac{L}{\sqrt{\varepsilon_{reff}}}, W_f = \frac{W}{2}$ from non-radiating edge. Calculations oflength and width of the design geometry has been calculated using equations (Garg Ramesh 2001 and Balanis C.A 1997). CADFEKO EM designed tool is utilized to simulate the antenna structure.

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

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

Where,

$$\frac{\Delta L}{h} = 0.412\frac{\left(\epsilon_{r_{eff}} + 0.3\right)\left(\frac{w}{h} + 0.2264\right)}{\left(\epsilon_{r_{eff}} - 0.258\right)\left(\frac{w}{h} + 0.8\right)} \quad (3)$$

$$\epsilon_{r_{eff}} = \frac{(\epsilon_r + 1)}{2} + \frac{(\epsilon_r - 1)}{2\sqrt{1 + 12\left(\frac{h}{w}\right)}} \quad (4)$$

$$L_{\mathrm{eff}} = \frac{c}{2 f_{\mathrm{r}} \sqrt{\epsilon_{r_{eff}}}} \quad (5)$$

Where
ε_{reff} = Effective Dielectric constant
C=Velocity of light in free space
Luff=Effective length of the Patch
ΔL=Length Extension of the Patch
To enhance bandwidth and operate antenna structure in Ultra-Wide Band range I-shaped slot is etched out on patch and notch on both side of radiating patch is introduced. The electrical dimensions of the patch are 0.298λ0×0.215λ0. The electrical dimension for the slot structure is:
For horizontal Arm: 0.09λ0 ×0.014λ0
For Vertical Arm: 0.014λ0 ×0.11λ0
λ0 is free space wavelength
I-Slot loaded microstrip patch is analyzed in two sections. Segment 1 is investigated as a patch in which only vertical notch is etched out. This I-slot vertical arm increase current length which is incorporated by an added series inductance ΔL along with series capacitance ΔC. So the capacitance and inductance of section 1 is modified in which

$$L2 = L + \Delta L \quad (6)$$

$$C2 = C + \Delta C \quad (7)$$

The value of additional inductance is calculatedby

$$\Delta L = \frac{Z_1 + Z_2}{16\pi \cos^{-2} \frac{\pi z_0}{L}} \tan\left(\frac{\pi fls}{c}\right) \quad (8)$$

The additional capacitance is given by,

$$\Delta C = 2ls\frac{\varepsilon_0}{\pi}\left[\left[\ln\left(\frac{2\left(1+\sqrt{k'}\right)}{\left(1+\sqrt{k'}\right)}\right)\right] + \ln\coth\frac{\pi d}{4h} + 0.013c\frac{h}{d}\right] \times \cos^{-2}\frac{\pi z_0}{L} \quad (9)$$

The second section has two microstrip bend line considering this the equivalent impedance of the shape is calculated as,

$$Zb = jWL_b + \frac{1}{\frac{1}{jWLb} + jWCb} \quad (10)$$

and

$$\frac{2Lb}{10} = 100\left(\sqrt{\frac{Wb}{h}} - 4.21\right) nH \quad (11)$$

Linking the above two segments, consider I-slot loaded patch. Antenna parameters changed due to change in slot length and width. S11 plot of antenna 1 and 2 shown in Figure. 3(a) and Figure. 3(b). It is perceived that resonating frequency moved towards higher side because of vertical arm length of I-slot. It is likewise observed that due to horizontal arm length patch resonates at lower frequency too. Along with I-slot vertical and horizontal arm length, introduced notch length and width adds inductance and capacitance in the equivalent circuit of I slot loaded patch. The length along with width of the notch varies which results into enhancement of bandwidth and helps to achieve wide bandwidth of 1.48GHz with 6.75dBi gain. For further improvement of bandwidth capacitive loading is introduced. It is observing that due to capacitive loading bandwidth of antenna reduced to 668MHz and also shows reduction in gain abruptly. It is because of capacitance dominates inductance and capacitive effect shows abrupt reduction in gain and bandwidth. To reduce capacitive effect gap between patch and capacitive loading is increased by 0.11λ0 which shows good improvement in Bandwidth as well gain. This antenna structure shown in Figure. 1(b) achieves impedance bandwidth of 2.16GHz with 3.08dBi gain. Simulated results of I-Slotted, Notch cut capacitive loaded microstrip patch antenna are presented.

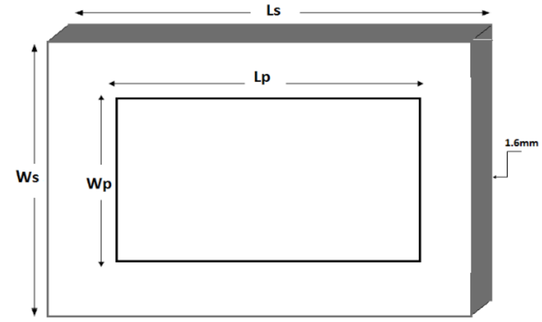

Figure 1(a). *Antenna 1*

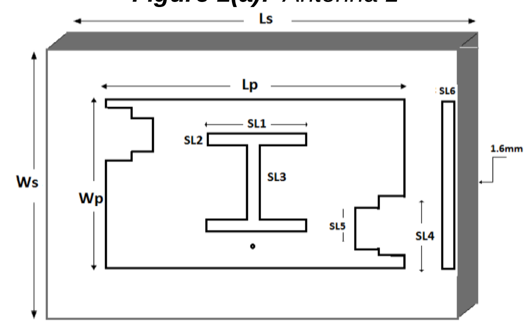

Figure 1(b). *Antenna 2*

3.PARAMETRIC STUDY

Parametric analysis performs on width of vertical side slots that shows resonant frequency changes as side slot width changes from 4.4mm to 4 and 4.8mm, antenna resonates at 5.17GHz and 3.29GHz at 4mm width and 5.25GHz and 6.31GHz at 4.8mm respectively. Current length changes because of introduction of slots and it cause to tuned antenna in wide band having substantial impedance bandwidth as compare to antenna 1 shows in Figure. 2(a). Table 1 shows effect of vertical outer slot of notch width variations.

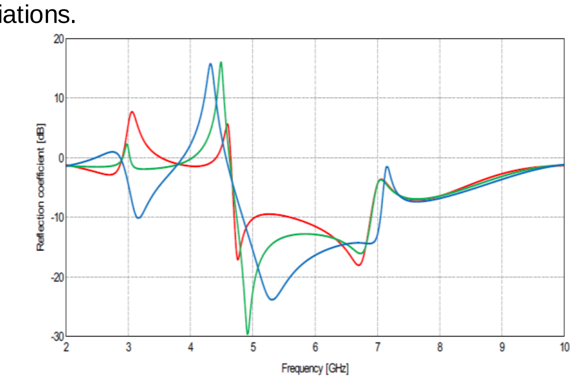

Figure 2(a) *Vertical Outer slot of Notch Length variation effect.*

Parametric analysis for vertical slot length is carried out and it shows resonant frequency changes as side slot length changes from 10mm to 10.5mm and 9.5mm, antenna resonates at 4.76GHz and 6.7GHz at 10.5mm length and 5.3GHz at 9.5mm respectively. Figure 2(b) shows significant effect of slot length on reflection coefficient as well bandwidth. Radiating patch need to modify to tune it at wide band suitable for biomedical application. Table 2 shows effect of vertical outer slot of notch length variations.

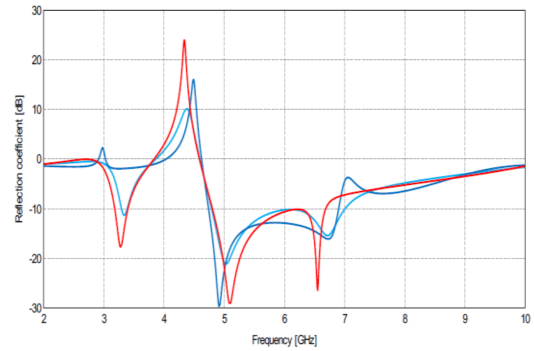

***Figure 2(b)**. Vertical inner slot of Notch width variation effect.*

TABLE 1

SIMULATED RESULTS

Resonant Frequency (GHz)	Reflection Coefficient (S11) dB	Band Width (GHz)	Gain (dB)	VSWR	Impedance(Ohm)
4.91	-29.78	2.16	3.31	1.07	46.6
5.17	-54.99	2.05	18.33	1.02	50.12
3.29	-18.7	230MHz	-0.95	1.29	46.97
5.25	-20.59	899MHz	13.23	1.02	41.61
6.31	-12.64	480MHz	28.55	1.29	34.18

TABLE 2

SIMULATED RESULTS

Resonant Frequency (GHz)	Reflection Coefficient (S11) dB	Band Width (GHz)	Gain (dB)	VSWR	Impedance (Ohm)
4.91	-29.78	2.16	3.31	1.07	46.6
4.76	-17.14	340MHz	-1.6	1.35	36.08
6.7	-18.1	1.3	9.36	1.29	36.38
5.3	-23.87	2.21	5.15	1.14	43.42

4. RESULTS AND DISCUSSION

Simulation results of reflection coefficient with frequency plot is presented in graph 3(a-b). Implemented structure results are listed in Table 3. Good matching between simulated and analytical results. Table 3 shows bandwidth and gain of both configurations

TABLE 3.

SIMULATED RESULTS

Sr. No.	Antenna Configuration	Resonating Frequency /Band	Reflection Coefficient (dB)	Gain (dB)	Band width
1	Antenna 1	2.456GHz (ISM Band)	-70.11	2.26	66MHz
2	Antenna 2	4.91GHz	-29.79	3.08	2.16GHz

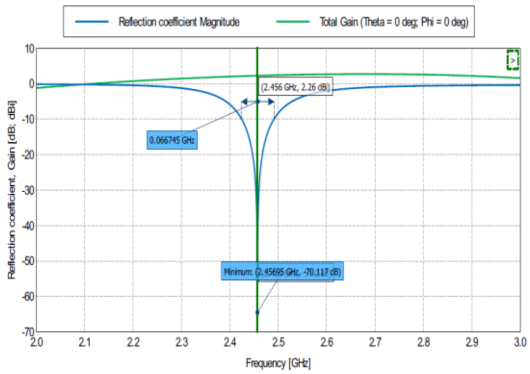

Figure 3(a). *Reflection Coefficient of Antenna 1*

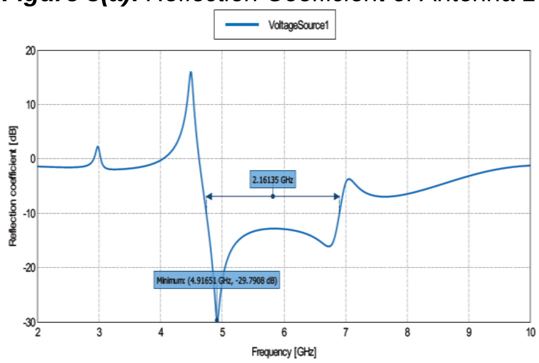

Figure 3(b). *Reflection Coefficient of Antenna 2*

5. CURRENT DISTRIBUTION

Surface current is linear in nature and excites TE01 mode which is fundamental mode, length of current increases after embedding slot on radiating patch. Capacitive loaded patch with I-Slot antenna tunes to wide band

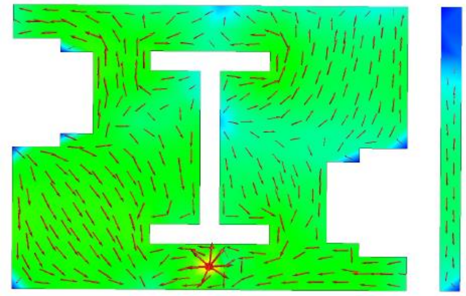

Figure 4. *Surface Current Distribution*

.

6. CONCLUSION

UWB antenna structure is designed and implemented designed configuration using CAD FEKO. Antenna 2 with I-slot, notch cut structure is implemented which gives impedance bandwidth of 2.16GHz resonating at 4.91GHz. Notch cut slots length is optimized which gives wide bandwidth of 2.16GHz with gain of 3.08dBi. To achieve this, gain capacitive loading plays vital role. Parametric analysis shows that slot length effect on performance of antenna. This antenna configuration will be useful for different RF and biomedical applications.

7. REFERENCES

[1] Chakraborty U., Kundu A., Chowdhury K.,and Bhattacharjee A.K., "Compact Dual-Band Microstrip Antenna for IEEE802.11a WLAN Application," IEEE Antenna and WirelessPropagation Letters, Vol.13, pp.407-410, 2014

[2] Zhang Y.P., "Design and Experiment on Differentially Driven Microstrip Antennas", IEEE transaction on antennaand wireless prorogation letters, vol.55, No.10, pp.2701-2708, October 2007

[3] Ansari J. A., and Ram R.B., "Broadband Stacked U-Slot Microstrip Patch Antenna," Progress in Electromagnetics Research Letters, Vol. 4, pp. 17-24, 2008

[4] Deshmukh A.A., and Ray K.P., "Compact Broadband Slotted Rectangular Microstrip Antenna," IEEE Antennas and Wireless Propagation Letters, Vol. 8, pp.1410-1413, 2009

[5] Ahire Dnyaneshwar, Kharate Gajanan., "Dual Band Microstrip Patch Antenna for Wireless Applications", International Journal of Computer Technology and Applications,10(8),2017 pp. 167-175 ISSN: 0974-5572,International Science Press

[6] Ahire Dnyaneshwar,BhirudS.R., "Defective Ground StructureMicrostrip Patch Antenna for ISM, Wi-MAX and C-Band Using U Slotted Structure, International Journal of AdvanceFoundation and Research in Computer, Volume 2,Issue 8 August - 2015. ISSN 2348 – 4853

[7] Joshi Jayant.G., Pattnaik Shyam S., and Devi S., "Geo-textile Based Metamaterial Loaded Wearable Microstrip Patch Antenna", International Journal of Microwave and Optical Technology, Vol. 8, No.1, January 2013

[8] Joshi J.G., Pattnaik Shyam S., and Devi S, "Rectangular Slotted Microstrip Patch Antenna with Partially Loaded Metamaterial Ground Plane", International Journal of Microwave and Optical Technology, Vol. 8, No.1, January 2013

[9] Mishra A., Singh P., Yadav N.P., and Ansari J.A., "Compact Shorted Microstrip Patch Antenna for Dual Band Operation," Progress in Electromagnetics Research, Vol. 9, pp. 171-182, 2009

[10] Sze J.Y., and Wong K.L., "Slotted Rectangular Microstrip Antenna for BandwidthEnhancement,"IEEETransaction on Antenna and Wireless Prorogation Letters, Vol.48, pp.1149-1152, August 2000

[11] Xiao Lei Sun, Lui L., Cheung S.W., and Yuk T.I., "Dual Band Antenna with Compact Radiator for 2.4/5.2/5.8 GHz WLAN Application,"IEEE Transaction Antennas Propagation, Vol.60, No.12, pp. 5924-5931,Dec 2012

[12] Islam M.T., "Multi Slotted Microstrip Patch Antenna for Wireless Communication, "Progress

inElectromagnetics Research Letters, Vol. 10, pp. 11-18, 2009

[13] Sharma S., and Vishvakarma B.R., “Analysis of Slot Loaded Microstrip Patch Antenna,” Indian Journal of Radio and Space Physics, Vol.3, pp.424- 430,December 2005

[14] Wong K.L., and Hsu W.H., “A Broad Band Rectangular Patch Antenna with a Pair of Wide Slits,” IEEE Transactions on Antennas and Propogation,Vol.49, No. 9, pp. 1345-1347, September 2001

[15] Weigand Steven, Huff Greg H., Pan Kankan H., and Bernhard Jennifer T., “Analysis and Design of Broad-Band Single-Layer Rectangular U-Slot Microstrip Patch Antennas”, IEEE Transactions on Antennas and Propogation, Vol. 51, No. 3, March 2003

[16] Ansari J. A., Khan R.U., VishvakarmaBabau R., “Analysis of U-Slot Loaded Patch for DualbandOperation,International Journal of Microwave and Optical Technology, Vol 3, No.2, April 2008

[17] Moosazadeh Mahdi and Kharkovsky Sergey, “Compact and Small Planar Monopole Antenna with Symmetrical L- and U-Shaped Slots for WLAN/WiMAX Applications”, IEEE Antennas and Wireless Propogation letters, Vol. 13, 2014

[18] Mudar A.,Joumayly Al, Aguilar Suzette M., Behdad Nader, and HagnessSusan C., “Dual-Band Miniaturized Patch Antennas for Microwave Breast Imaging,”, IEEE Antennas and Wireless Propogation letters, Vol. 9, 2010

[19] Yeap Siew Bee, and Chen Zhi Ning, “Microstrip Patch Antennas with Enhanced Gain by Partial Substrate Removal, IEEE Transactions on Antennas and Propogation, Vol. 58, No. 9, September 2010

[20] Garg R. “Microstrip patch antenna design handbook, Artech House,” 2001

[21] Balanis Constantine A. Balanis; Antenna Theory, Analysis and Design, John Wiley & Sons Inc 2nd edition 1997.

[22] AhireDnyaneshwar., Bhirud S.R., “Performance Enhancement of Microstrip Patch Antennas Using Slotting: A Review, International Journal of Advance Foundation and Research in Computer, Volume 2,Issue 8, August - 2015. ISSN 2348 – 4853.