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Compact Notch Loaded Microstrip Patch Antenna for Wide Band Application

Saurabh Sharma[#], Anil Kumar[#], A. K. Jaiswal[#], Ashish Singh[*]

Department of Electronics and Communication [#*]
Sam Higginbottom Institute of Agriculture, Technology and Sciences [#]
University of Allahabad*
Allahabad, India

Abstract – In this paper, compact notch loaded microstrip antenna is analyzed using Zeland IE3D simulator and circuit theory concept. Analysis on varying thickness, dielectric constant, length and width of the notch has been reported. The bandwidth obtained by the proposed antenna is about 41.8%.

Key Words- Wide band, Microstrip Patch Antenna, Return Loss, Dielectric Substrate.

I. INTRODUCTION

The development of the modern wireless communication leads to the need of wideband antennas. Wideband antennas have found wide spread application in wireless communication industry due to their attractive features like easy fabrication, low cost, linearly and circularly polarized radiation characteristics. Due to these attractive features wideband antennas are used in many wireless applications such as Wi-Fi, Bluetooth, GSM and GPRS. In previous years many researchers has tried to improve the bandwidth(2-3%) of the microstrip antennas, they have reported numerous method like aperture coupling[1], use of shorting pins and walls [2-4], stacking [5-7] etc. to enhance the bandwidth of the microstrip antenna.

In this paper we have proposed simple geometry of wideband antenna that give 41.8% of the bandwidth while previous researcher have reported complicated geometry having wideband operation[8,9]. The parameters of the antenna are analyised using Zeland IE3D simulator.

II.THEORETICAL CONSIDERATIONS

The geometry of proposed microstrip patch antenna is shown in Fig.1.

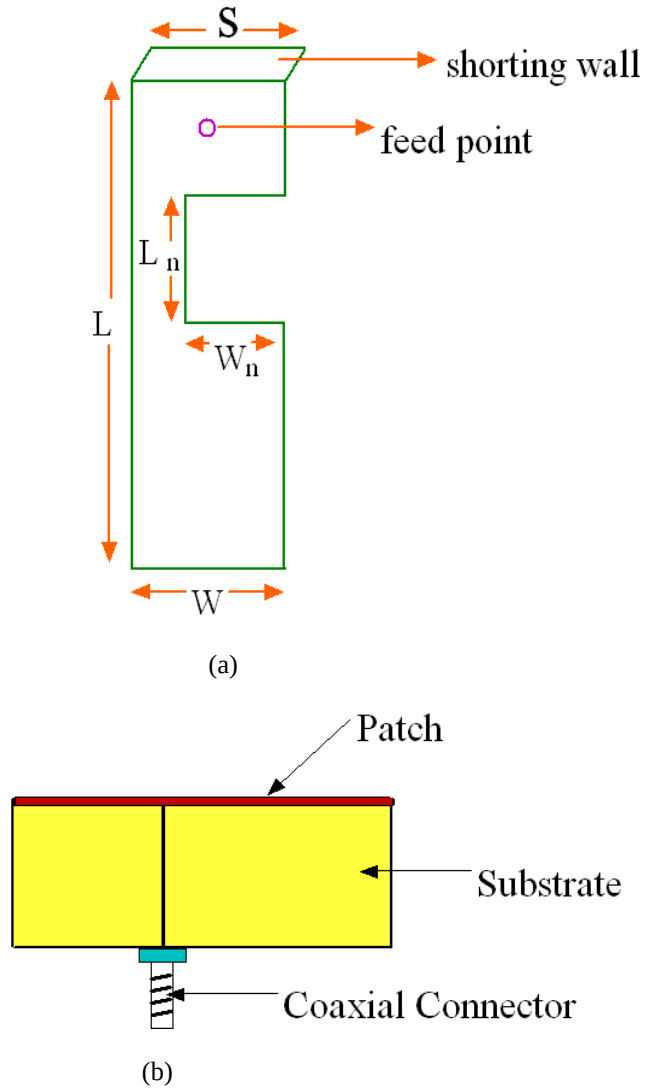


Fig.1. Geometry of notch loaded shorted wall microstrip patch antenna (a) Top View, (b) Side View.

A. Analysis of Rectangular Patch Antenna

A simple rectangular microstrip patch antenna can be considered as a parallel combination of resistance (R_P), inductance (L_P) and capacitance (C_P) as shown in Fig.2.

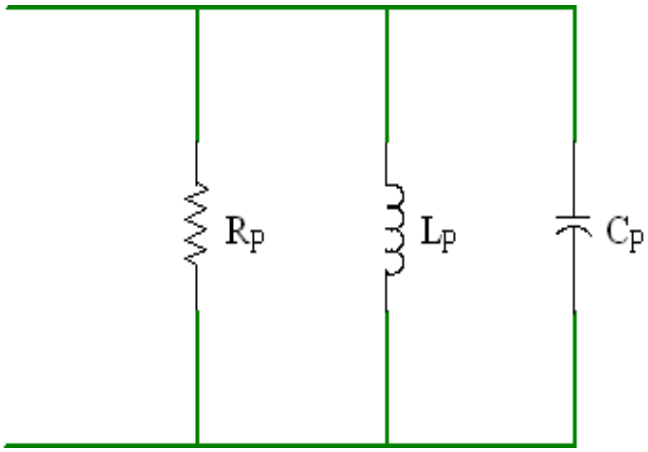


Fig.2. Equivalent circuit of the rectangular patch.

The value of R_P,L_P and C_P can be given as [10]

$$C_P = \frac{\varepsilon_0 \varepsilon_e LW}{2h} cos^{-2}\left(\frac{\pi y_0}{L}\right) \quad (1)$$

$$L_P = \frac{1}{\omega^2 C_P} \quad (2)$$

$$R_P = \frac{Q_r}{\omega C_P} \quad (3)$$

Where,

L= length of the rectangular patch.
W= width of the rectangular patch.
y_0= location of feed point.
h= thickness of the substrate material.
And

$$Q_r = \frac{c\sqrt{\varepsilon_e}}{4fh}$$

Where,

c = speed of light
f = design frequency
ε_e = effective permittivity of the medium [10]

$$\varepsilon_e = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + \frac{10h}{W}\right)^{-1/2} \quad (4)$$

Where,

ε_r = relative permittivity of the substrate material.

Therefore for Fig.2 input impedance of the rectangular patch is given by.

$$Z_{Patch} = \frac{1}{\frac{1}{R_P} + \frac{1}{j\omega L_P} + j\omega C_P} \quad (5)$$

B. Analysis of Notch Loaded Rectangular Patch Antenna.

The notch is loaded along one side of the rectangular patch; this causes an additional series capacitance C_0 and inductance L_0 as shown in Fig.3.

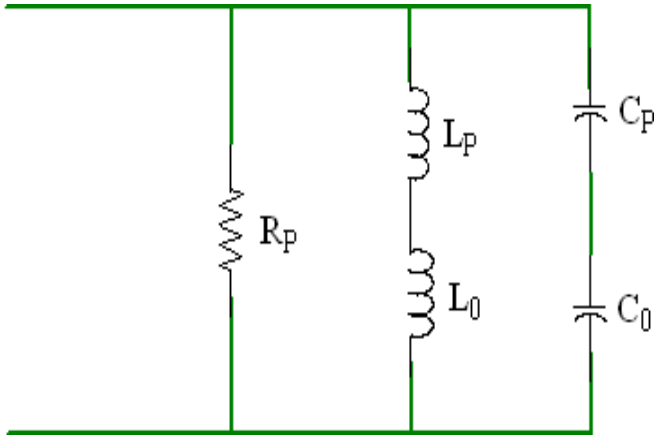


Fig.3. Equivalent circuit of notch loaded patch antenna

Thus,

$$C_T = \frac{C_P C_0}{C_P + C_0} \quad \text{and} \quad L_T = L_P + L_0$$

The value of L_0 and C_0 can be calculated can be calculated as [11, 12].

$$L_0 = \frac{h\mu_0\pi}{8}\left({}^{L_n}/_{L}\right)^2$$

$$C_0 = \left({}^{L_n}/_{L}\right) C_s$$

Where,

$\mu = 4\pi \times 10^{-7}\ {}^{H}/_{m}$

L_n= length of the notch.

C_s = gap capacitance [13].

$$Z_{notch} = \frac{j\omega R_P L_T}{j\omega L_T + R_P - R_P L_T C_T \omega^2} \quad (6)$$

C. Analysis of shorted wall rectangular patch Antenna.

The shorting wall is used along one side of the rectangular patch this causes additional inductance L_s and resistanceR_s.

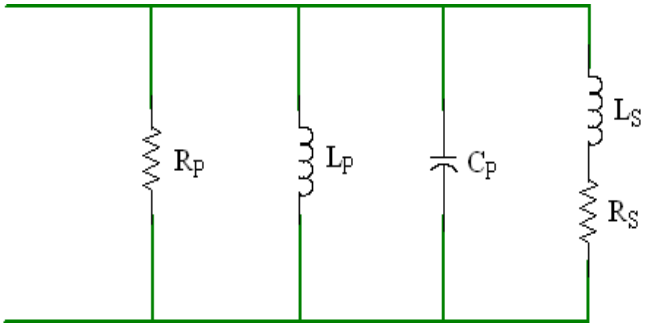


Fig.4. Equivalent circuit of the shorted patch antenna.

$$Z_{short} = \frac{R_P j\omega}{j\omega + L_e R_P - R_P C_P \omega^2} \quad (7)$$

Where, $L_e = \frac{L_S + L_P}{L_S L_P}$

Where, L_s= Shorting wall inductance [10]

L_s = 0.2 h $\left[\log \frac{2h}{(S+t)} + 0.2235 \frac{(S+t)}{h} + 0.5\right]$

S= length of the shorting wall.

h = thickness of the dielectric substrate.

t= thickness of the shorting wall.

D. Analysis of notch loaded shorted rectangular patch Antenna.

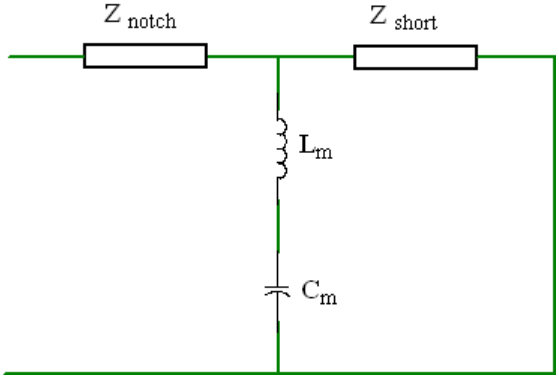


Fig.5. Equivalent circuit of coupled notch loaded shorted patch antenna.

The total input impedance of the notch loaded shorted patch antenna as shown in Fig.5. is given as,

$$Z_{total} = Z_{notch} + \frac{Z_{short} Z_m}{Z_{short} + Z_m} \quad (8)$$

Where, $Z_m = \left(j\omega L_m + \frac{1}{j\omega C_m}\right)$

L_m and C_m are the mutual inductance and mutual capacitance between two resonant circuit [14].

$$L_m = \frac{C_Z{}^2(L_P+L_T) + \sqrt{C_Z{}^2(L_P+L_T)^2 + 4C_Z{}^2(1-C_Z{}^2)L_P L_T}}{2(1-C_Z{}^2)}$$

$$C_m = -\frac{(C_P + C_T) + \sqrt{(C_P+C_T)^2 - 4\,C_P C_T(1-C_Z{}^{-2})}}{2}$$

Where, $C_Z = \frac{1}{\sqrt{q_1 q_2}}$ and $q_1 and q_2$ are quality factor of the two resonant circuits.

III. DESIGN SPECIFICATION

Table 1. Design specifications for the notch loaded shorted patch antenna.

Substrate material used	RT-duroid 5880
Relative permittivity of the substrate (ε_r)	2.20
Length of the patch (L)	42 mm
Width of the patch (W)	14 mm
Length of the notch (L_n)	11 mm
Width of the notch (W_n)	9 mm
Length of the shorting wall (S)	14 mm
Thickness of the dielectric substrate (h)	2.3 mm
Feed point (x_0,y_0)	(0,17)

IV. RESULTS AND DISCUSSION

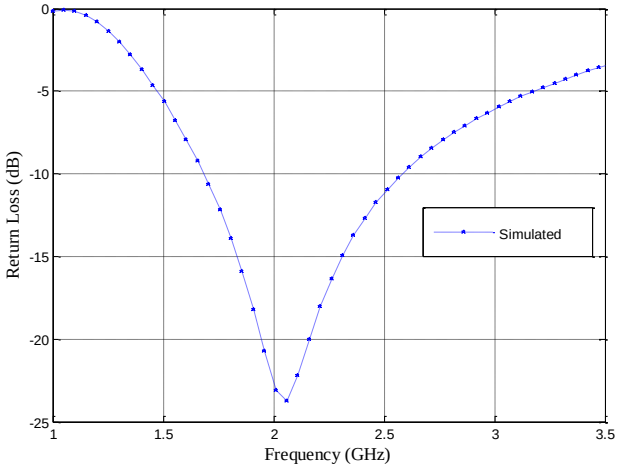


Fig.6. Variation of return loss with frequency for proposed antenna.

The variation of the return loss with frequency for notch loaded shorted patch antenna is shown in Fig.6 it is observed that the antenna has the bandwidth of 41.80%.

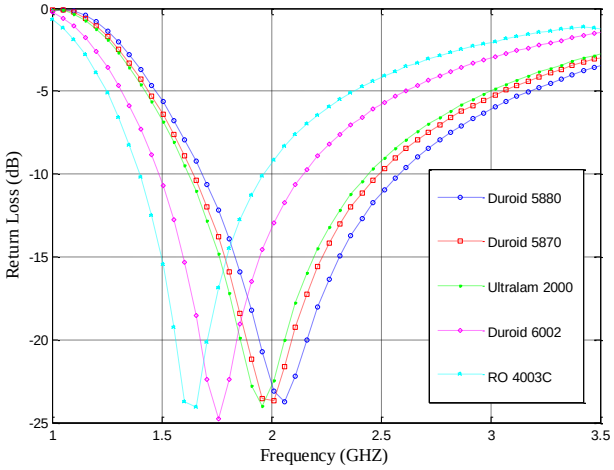


Fig.7. Variation of return loss with frequency for different dielectric substrate.

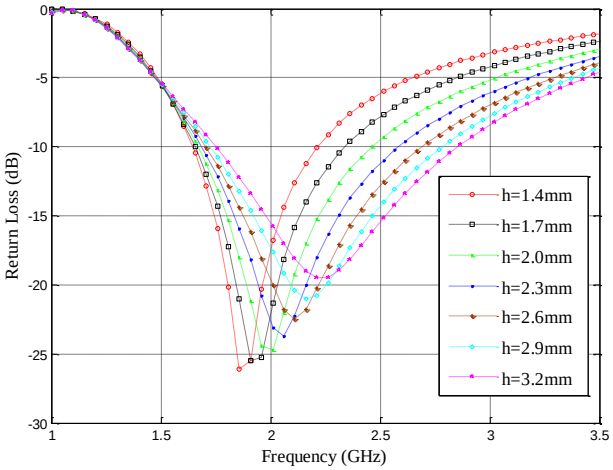


Fig.8. Variation of return loss with frequency for different thickness of dielectric substrate.

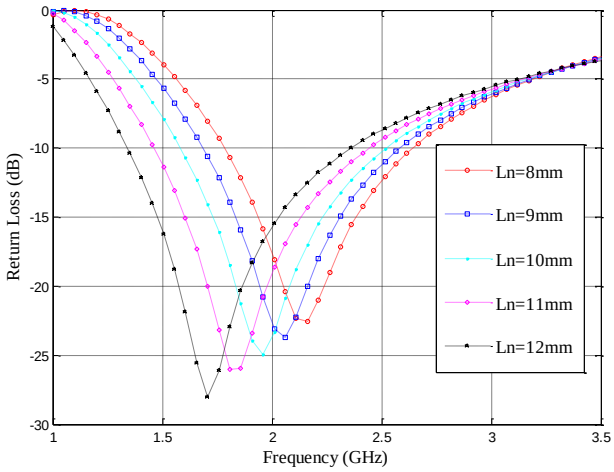


Fig.9. Variation of return loss with frequency for different notch length (L_n).

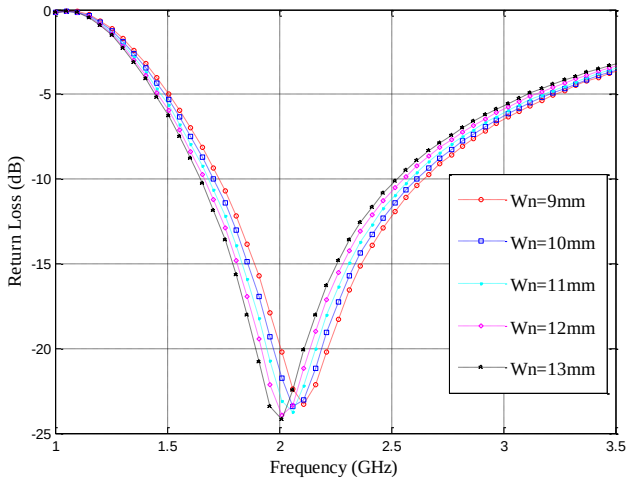


Fig.10. Variation of return loss with frequency for different notch width (W_n).

Table 2. Calculated value of the bandwidth for different dielectric substrate.

S.No	Product	Dielectric Constant (ε_r)	Frequency band (GHz)	Center Frequency (GHz)	Bandwidth
1.	Duroid5880	2.20	1.68612- 2.57729	2.131705	41.80%
2.	Duroid5870	2.33	1.64669-2.48265	2.06467	40.49%
3.	Ultralam2000	2.40	1.62303-2.44322	2.033125	40.34%
4.	Duroid6002	2.94	1.48896-2.14353	1.816245	36.04%
5.	RO4003C	3.38	1.40221-1.96215	1.68218	33.29%

On increasing the dielectric constant (ε_r) has decreasing effect on bandwidth which shifts towards lower side Fig.7.

Table 3. Calculated value of the bandwidth for different thickness of the dielectric substrate (h).

S.No	Dielectric thickness (h)	Frequency band (GHz)	Center frequency (GHz)	Bandwidth
1.	1.4 mm	1.64669-2.21451	1.9306	29.41%
2.	1.7 mm	1.65457-2.34069	1.99763	34.35%
3.	2.0 mm	1.67035-2.45899	2.06467	38.20%
4.	2.3 mm	1.68612-2.57729	2.131705	41.80%
5.	2.6 mm	1.70189-2.6877	2.194795	44.41%
6.	2.9 mm	1.72555-2.78233	2.25394	46.88%
7.	3.2 mm	1.7571-2.85331	2.305205	47.55%

On increasing the thickness of the dielectric (h) has increasing effect on bandwidth which shifts towards upper side Fig.8

Table 4. Calculated value of the bandwidth for different value of notch length (L_n).

S.No.	Notch length (L_n)	Frequency band (GHz)	Center frequency (GHz)	Bandwidth
1.	8 mm	1.78076-2.64038	2.21057	38.88%
2.	9 mm	1.68612-2.57729	2.131705	41.80%
3.	10 mm	1.5836-2.5142	2.0489	45.42%
4.	11 mm	1.4653-2.44322	1.95426	50.04%
5.	12 mm	1.33912-2.35647	1.847795	55.05%

On increasing the notch length (L_n) has increasing effect on bandwidth which shifts towards lower side Fig.9.

Table 5. Calculated value of the bandwidth for different value of notch width (W_n).

S.No	Notch width (W_n)	Frequency band (GHz)	Center frequency (GHz)	Bandwidth
1.	9	1.73344-2.64038	2.18691	41.47%
2.	10	1.70978-2.60883	2.159305	41.63%
3.	11	1.68612-2.57729	2.131705	42.27%
4.	12	1.66246-2.55363	2.108045	42.27%
5.	13	1.64669-2.52997	2.08833	42.30%

On increasing the notch width(W_n) has increasing effect on bandwidth which shifts towards lower side Fig.10.

V. CONCLUSION

From the analysis, it is found that the bandwidth of the proposed antenna depends upon dielectric substance, thickness of the substrate and dimension of the notch, proposed antenna can be utilized for various wireless applications.

VI. REFERENCES

[1] C.-H.Lai, T.-Y. Han and T.-R. Chen, "Broadband aperture Coupled microstrip antennas with low cross polarization and back radiation," Progress In Electromagnetic Research Letters, Vol. 5,187-197, 2008.

[2] A.Mishra, P.singh, N.P.Yadav and J.A.Ansari, "Compact Shorted Microstrip Patch Antenna for Dual Band Operation," Progress In Electromagnetic Research C, Vol. 9, 171-182, 2009.

[3] M.Abbaspour, and H. R. Hassani, "Wideband star-shaped microstrip patch antenna," Progress In Electromagnetic Research Letters, Vol. 1, 61-68, 2008.

[4] Osman, H. A., E. A. Aballah, and A. A. Abdel Rhim, "A novel broadband compact circular disk microstrip antenna for wireless applications," PIERS Online, Vol. 4, No. 7, 761-766, 2008.

[5] J. A. Ansari, and R. B. Ram, "Broadband stacked U-slot microstrip patch antenna," Progress In Electromagnetic Research Letters, Vol. 4, 17-24, 2008.

[6] E.Nishiyama and M.Aikawa, "FDTD Analysis of stacked microstip antenna with high gain," Progress In Electromagnetic Research, PIER 33, 29-43, 2001.

[7] J. A. Ansari, P. Singh, S. K. Dubey, R. U. Khan, and B. R. Vishwakarma, "Analysis of stacked V-slot loaded patch antenna for wideband application," Microwave and Optical Technology Letters, Vol. 51, No. 2, 324-330, 2009.

[8] M.Sanda, "A Wide Band Microstrip Antenna for Portable Cordless Telephones," IEEE Antennas and Propagation Symposium Digest, June 1995, pp. 1132-1135.

[9] G.Yang, M.Ali and R.Dougal, "A Wideband Circularly Polarized Microstrip Patch Antenna For 5-6 Ghz Wireless LAN Applications," Microwave and optical technology letters, Vol.45, No.4, May 20 2005.

[10] R. Garg, P. Bhartia, I.J. Bahl and A.Ittipiboon, Microstrip antenna design hand book, Artech house New York 2001.

[11] X. X. Zhang, and F. Yang, "Study of slit cut microstrip antenna and its application," Microwave Opti. Technol. Lett., Vol.18, 297-300, 1998.

[12] I.J.Bahal, Lumped Elements for RF and Microwave Circuits, Artech House, Boston, 2003.

[13] M. K Meshram, and B. R. Vishvakarma, "Gap-coupled microstrip array antenna for wide band operation," Int. J. Electronics, Vol. 88, 1161, 2001.

[14] V.K.Pandey and B.R.Vishvakarma,"Theoretical analysis of linear array antenna of stacked patches," Indian J. Radio & Space Phys., Vol.3, 125-127, 2005.

AUTHOR'S PROFILE

SAURABH SHARMA



Received his B.Tech degree in Electronics & Communication Engineering from B.B.S.College of Engineering & Technology, Allahabad. Presently he is Pursuing his M.Tech in Electronics and Communication Engineering (Communication System Engineering) from *SAM HIGGINBOTTOM INSTITUTE OF AGRICULTURE, TECHNOLOGY AND SCIENCES, Allahabad.* His research interests are Microstrip patch Antenna and Optical Communication.
E-mail Id- saurabh5771@gmail.com

ANIL KUMAR



Is working as an Assistant Professor in the Department of ECE at *SAM HIGGINBOTTOM INSTITUTE OF AGRICULTURE, TECHNOLOGY AND SCIENCES, Allahabad.* He received the degree of M.Tech from IIT BHU. He is pursuing Ph.D. He has presented & published various research papers in national and international journals and conferences. His research interests are VLSI; Microstrip Antenna & Artificial Neural Network.

A.K. JAISWAL



Is working as professor and HOD in the department of ECE at *SAM HIGGINBOTTOM INSTITUTE OF AGRICULTURE, TECHNOLOGY AND SCIENCES, Allahabad.* He worked for the promotional activities in optical fiber communication system sponsored by Government of India, in association with IIT Kharagpur and Madras. His research interests are Optical system, sensors and networks.

ASHISH SINGH



Is pursuing Ph.D from J.K. Institute of Applied Physics & Technology (University of Allahabad), Allahabad. He received the degree of M.Tech from J.K. Institute of Applied Physics & Technology (University of Allahabad), Allahabad. He has presented & published various research papers in national and international journals and conferences. His research interests are Microstrip patch Antenna and Optical Communication.