

Bandwidth Enhancement by Loading the Rectangular Microstrip Patch Antenna with I-Slot for Broadband Applications

Sunil Kumar¹, N.S.Beniwal², D.K.Srivastava³

^{1,2,3}Digital Communication, B.I.E.T., Jhansi, U.P., India

Abstract: In this paper, the bandwidth of rectangular Microstrip antenna is enhanced by 'I' slotted rectangular microstrip patch antenna. In some applications which the increased bandwidth is needed, proposed antenna is one of the alternative solutions. The proposed antenna has been designed at the 2 GHz frequency. The frequency band of proposed antenna is in between (1.64-3.26 GHz) the fractional bandwidth is 66.12% which is suitable for broad band applications. The gain has been improved up to 4.98dBi, directivity 4.99dBi and efficiency 99.68%. The proposed 'I' slotted Microstrip antenna is fed by 50Ω Microstrip feed line. The antenna design and performance of 'I' slotted micro-strip antenna is simulated by IE3D zeeland software.

Keywords: I-slotted, enhance bandwidth, Microstrip Rectangular Patch, calculated ground plane, gain, 50Ω feed line.

I. Introduction

In today's modern communication industry, antennas are the most important components required to create a communication link. Microstrip patch antennas are increasingly used structure in various wireless applications fields [1] such like mobile phone, radio, laptop with wireless connection [2]. The development of antenna for wireless communication also requires an antenna with more than one operating frequency. This is due to many reasons, primarily because of various wireless communication systems and many telecommunication operators use various frequencies. The concept of Micro strip antenna was first proposed in 1953, twenty years before the practical antennas were produced. Since the first practical antennas were developed in early 1970's, interest in this kind of antennas was held in New Mexico [3]. The bandwidth of Microstrip antenna may be increased using several techniques such as use of a thick or foam substrate, cutting slots or notches like U slot, E shaped H shaped patch antenna, introducing the parasitic elements either in coplanar or stack configuration, and modifying the shape of the radiator patch by introducing the slots[4, 5, 6,7]. Microstrip antenna has been established as a separate entity in the field of microwave antenna because of its numerous advantages such as in communication base stations, and as small size, light weight, low profile, low cost, and ease of integration with other microwave components. It is being used in large variety of applications such as radar, missiles, aircraft, satellite communications, and mobile handsets as well as in biomedical telemetry services [8]. The disadvantages of microstrip antenna are their limited band width. Researchers investigated method to increase the bandwidth of microstrip patch antenna. The proposed I-slotted rectangular microstrip patch antenna is proved to be one of the effective methods in enhancement of bandwidth. Further enhancement in the antenna bandwidth is achieved by cutting rectangular slots at the edges of I-slot in figure 1. The proposed antenna has been designed on glass epoxy substrate ($\epsilon_r=4.2$) [9, 10]. The substrate material has large influence in determining the size and bandwidth of an antenna. Increasing the dielectric constant decreases the size but lowers the bandwidth and efficiency of the antenna while decreasing the dielectric constant increases the bandwidth but with an increase in size. The design frequency of proposed antenna is 2 GHz. The frequency band(1.64-3.26GHz) of proposed antenna is suitable for broad band applications (1.605-3.381GHz) such as military, wireless communication, satellite communication, global positioning system (GPS), RF devices, WLAN/WI - MAX application [7, 11, 12].

II. Antenna Design

The mathematical formula is used to calculate the dimensions of ground plane and patch in the form of length and width.
A. Width formula of Rectangular MSP is taken by [7, 10].

$$W = \left(\frac{c}{2f_r} \right) \left(\frac{\epsilon_r + 1}{2} \right)^{-0.5} \quad \text{Where } c = 3 \times 10^8 \text{ ms}^{-1}, \epsilon_r = 4.2, f_r = 2 \text{ GHz}$$

B. Formula of effective dielectric constant is taken by [9, 13].

C.

$$\epsilon_{eff} = \left(\frac{\epsilon_r + 1}{2} \right) + \left(\frac{\epsilon_r - 1}{2} \right) \left(1 + \frac{12h}{W} \right)^{-0.5}$$

At h=1.6mm

D. Formula of length extension is taken by [9, 10].

$$\Delta L = .412h \left(\frac{\epsilon_{eff} + .3}{\epsilon_{eff} - .258} \right) \left(\frac{\left(\frac{W}{h} \right) + .264}{\left(\frac{W}{h} \right) + .8} \right)$$

E. Length formula of Rectangular MSP is taken by [7, 12].

$$L = \left(\frac{c}{2f_r \sqrt{\epsilon_{eff}}} \right) - 2\Delta L$$

F. Formula of length and the width of the ground plane are taken by [10, 11].

$$L_g = L + 6h$$

$$W_g = W + 6h$$

III. Antenna Parameters

The design of proposed antenna is shown in Figure1. The proposed antenna is designed by substrate which has a dielectric constant 4.2 and the design frequency is 2 GHz.

Height of the dielectric substrate is 1.6 mm and loss tangent $\tan \delta$ is 0.0013. Antenna is fed through 50Ω Microstrip feed line. Antenna dimensions are given in table1 and other parameters are given in the table 2 (lengths in mm and frequency in GHz).

Table 1: Parameters For Antenna Design.

Sr.No.	Parameters	Value
1.	Design frequency f_r	2.0
2.	Dielectric constant ϵ_r	4.2
3.	Substrate height	1.6
4.	Loss tangent , $\tan \delta$.0013

Table 2: Designed Structure parameters

Sr.No.	Parameters	Value
1.	Ground plane width , a	55.44
2.	Ground plane length , b	43.86
3.	Patch width , c	39.06
4.	Patch length , d	50.44
5.	e	28.26
6.	f	5
7.	g	6
8.	h	40.64
9.	i	23.26

10.	j	10.2
11.	k	6.2
12.	l	15.44
13.	m	10

IV. Antenna Design Procedure

All the dimensions of proposed antenna are calculated by using the formulas A to E. Design frequency taken is 2 GHz. The rectangular patch is first grown and then it is loaded with I slot as shown in Figure1.

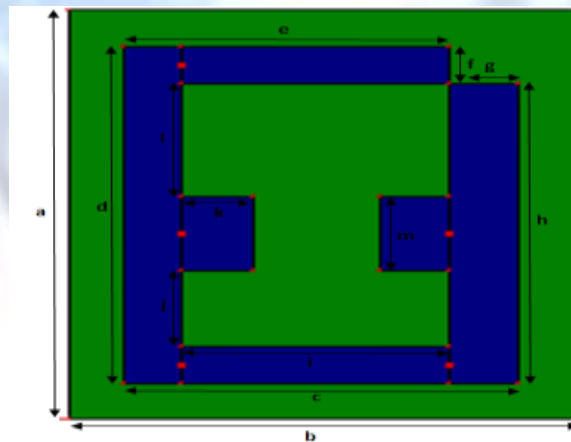


Figure 1: Geometry of proposed antenna

V. Simulation Result And Discussion

The proposed rectangular microstrip antenna studied successfully and it is found that it provides 66.12% high bandwidth and return loss upto -24.96 dBi. The narrow bandwidth of Microstrip antenna is one of the important features that restrict its wide usage. From the above it is clear that I-slot patch antenna which provides high bandwidth and high return loss. The maximum gain of the antenna has been improved up to 4.98 dBi, directivity improved up to 4.99 dBi, efficiency of the antenna is found to be 99.68%, and the VSWR of the antenna is in between 1 to 2 over the entire frequency band which shows good impedance matching.

The simulation performance of proposed micro strip patch antenna is analyzed by using IE3D simulation software version 9.0 at select design frequency of 2 GHz. The performance specifications like gain, radiation pattern etc of proposed antenna is shown in the Figures 2 to 10.

The plot graph of return loss Vs frequency is taken at the maximum frequency of 3.5GHz which is shown in Fig. 2. The enhances bandwidth 1620MHz (66.12% fractional bandwidth) of design antenna is obtained at calculated resonant frequency of 2.881GHz.

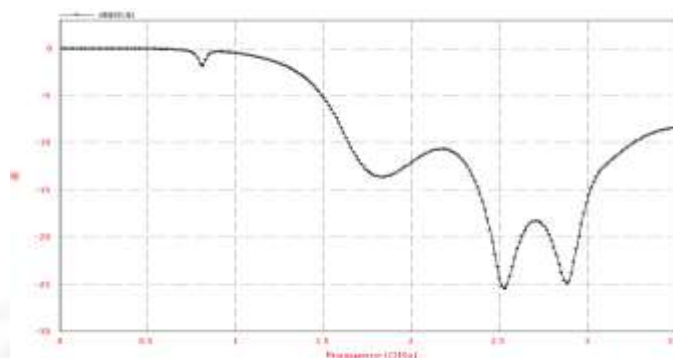


Figure 2: Return loss v/s frequency graph.

In Figure 3, the plot graph of 3D Radiation pattern of proposed antenna at resonant frequency 2.881 GHz.

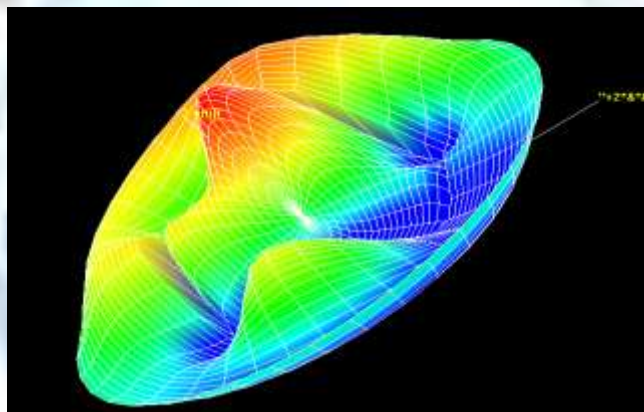


Figure 3: 3D Radiation pattern of proposed antenna.

In Figure 4, the plot graph of Gain Vs Frequency shows the total field gain of the MSP antenna and obtain maximum gain of antenna is 4.98dBi at resonant frequency 2.881GHz.

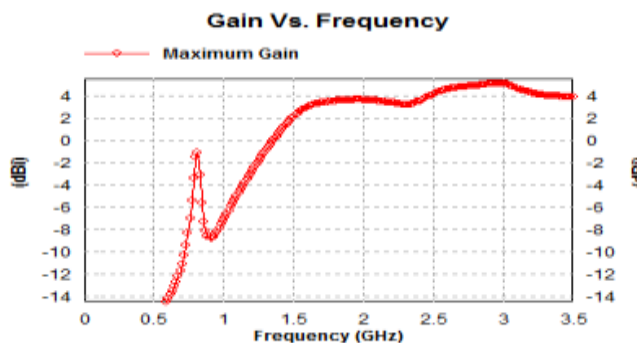


Figure 4: Gain vs. frequency plot

In Fig. 5, the plot graph of VSWR Vs Frequency represents that the bandwidth of design antenna is useful or not. The obtain VSWR is 1.12 at resonant frequency of 2.881GHz.

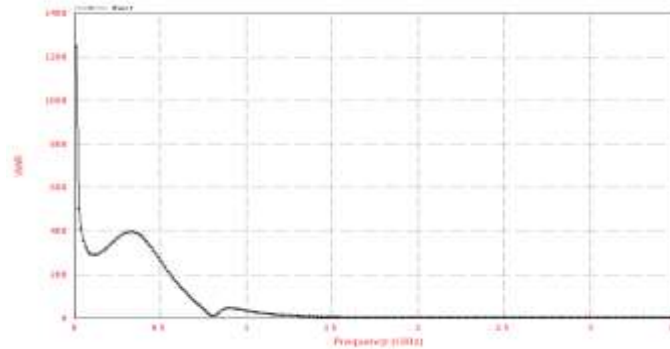


Figure 5: VSWR of proposed antenna

In Figure 6, the plot graph of total field Directivity Vs Frequency represents the ratio of radiation intensity in a given direction from the antenna to the radiation intensity averaged over all direction [16]. The obtain directivity of antenna is 4.99dB at resonant frequency 2.881GHz.

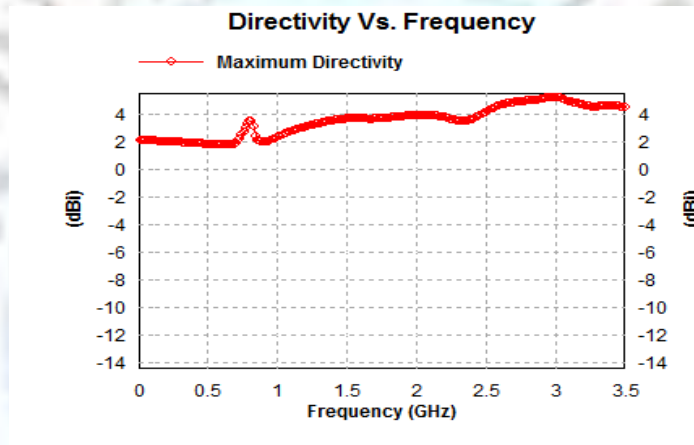


Figure 6: Directivity v/s frequency plot

In Figure 7, the plot graph of Smith chart of proposed antenna at resonant frequency 2.881 GHz.

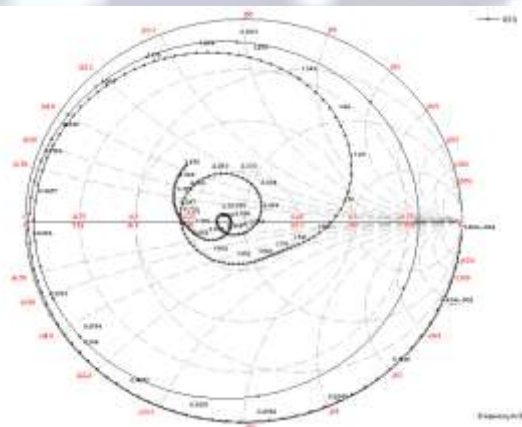


Figure 7: Smith chart

In Figure 8, the plot graph of 2D radiation pattern of antenna represents radiating all power in one direction therefore design antenna has unidirectional radiation pattern. 2D radiation pattern of antenna is shown at resonant frequency 2.881GHz and $\phi=0(\text{deg})$.

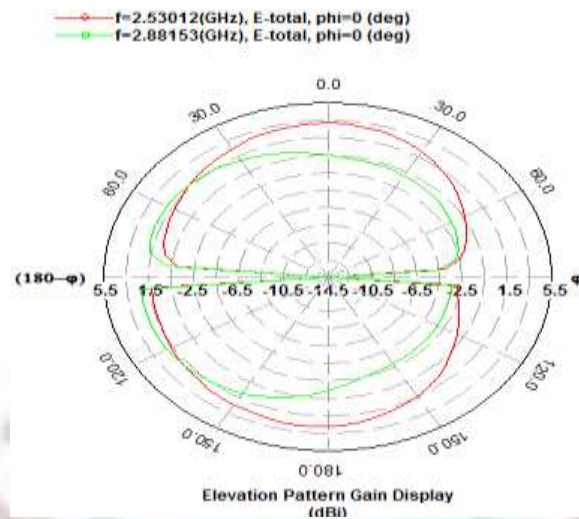


Figure 8: 2D radiation pattern of antenna

In Figure 9, the plot graphs of Efficiency Vs Frequency represent antenna efficiency. The obtain percentage antenna efficiency is 99.89% at 2.881GHz.

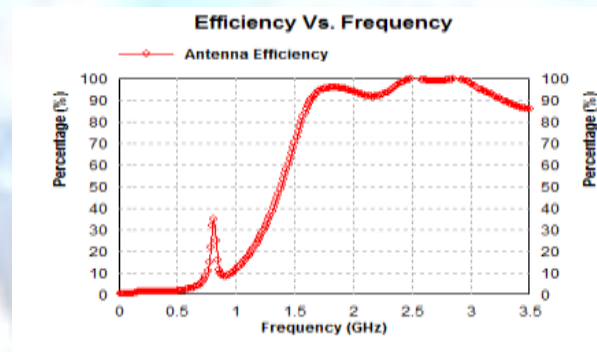


Figure 9: Efficiency graph of proposed antenna.

In Figure 10, the plot graph of Axial-Ratio Vs Frequency represents the ratio of the major axis to the minor axis of the polarization ellipse and the resulting pattern shows an oscillating pattern [15].

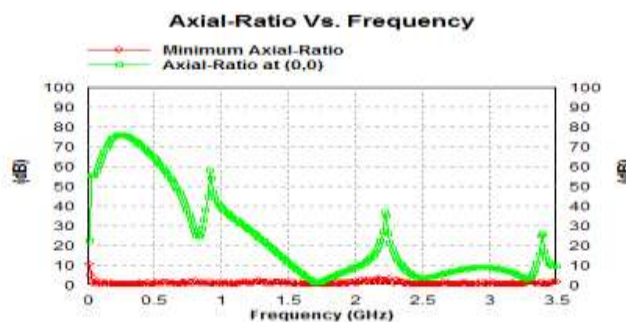


Figure 10: Axial-ratio vs. frequency plot

Acknowledgment

The authors gratefully acknowledge the support to carry out this study and work from Electronic and Comm. Engineering department of Bundelkhand Institute of Engineering and Technology, Jhansi, Uttar Pradesh, India

Conclusion

A novel technique for enhancing bandwidth of a microstrip patch antenna with single band characteristics and wide bandwidth capability for broad band applications is successfully designed and discussed. Microstrip patch antenna for broad band applications covering 1.64 to 3.26 GHz frequency has been presented. The proposed rectangular microstrip antenna it provides 66.12% high bandwidth, return loss up to -24.96dBi and efficiency 99.68 %. The simulated result of design antenna shows good performance and thus can be used as various broadband applications such as missile, wireless, satellite, mobile communication, and military.

References

- [1]. Bedri A. Cetiner, Franco De Flaviis, and Luis Jofre, "Miniature Multi-Element Antenna for Wireless Communications", IEEE Transactions On Antennas And Propagation, Vol. 50, No. 5, May 2002.
- [2]. Avisankar Roy, and Sunandan Bhunia, "Compact Broad Band Dual Frequency Slot Loaded Microstrip Patch antenna with Defecting Ground Plane for WI-MAX and WLAN," IJSCE, ISSN: 2231-2307, Vol.1, Issue-6, January -2012.
- [3]. M. Amman, Design of Microstrip Patch Antenna for the 2.4 Ghz Band, Applied Microwave and Wireless, pp. 24-34, November /December 1997.
- [4]. Parikshit Vasishth and Taruna Gautam, "Design of V-Slotted Trapezoidal Patch Antenna in WI-MAX Band Using Optimized Feed Location Method", IJETAE, ISSN: 2250-2459, Vol.2, Vol. 2, Issue 6, June - 2012.
- [5]. D.Pavithra and K.R.Dharani, "A Design of H-Shape Microstrip Patch Antenna for WLAN Applications", IJESI, ISSN: 2319-6734, Vol. 2, pp.71-74, Issue 6, June - 2013.
- [6]. Zakir Ali, Vinod Kumar Singh, Shahanaz Ayub, "A Neural Network Approach to study the Bandwidth of Microstrip Antenna", Volume 3, Issue 1, January 2013 ISSN: 2277 128X.
- [7]. D. Bhattacharya and R. Prasanna "Bandwidth Enrichment for Micro-strip Patch Antenna Using Pendant Techniques", IJER, ISSN: 2319-6890, Volume No.2, Issue No. 4, pp. 286-289, Aug. – 2013.
- [8]. [8]. J.-S. Hong, E.P. McElean, and B. Karyamapudi, Eighteen-pole superconducting CQ filter for future wireless applications, IEE Proc Microwave Antennas Propag 153 (2006), 205–211.
- [9]. T.Jayanthi, M.Sugadev, J.M. Ismael and G.Jegan, "Design and Simulation of Microstrip M- Patch Antenna with Double Layer", IEEE Trans., AP- 978-1-4244-2690-4444, 2008.
- [10]. Constantine A. Balanis, "Antenna theory, Analysis and Design", John Wiley & Sons, Inc Hoboken, New Jersey, 2005.
- [11]. Sukhbir Kumar and Hitender Gupta "Design and Study of Compact and Wideband Microstrip U-Slot Patch Antenna for WI-Max Application", IOSR-JECE, ISSN: 2278-2834, Vol. 5, Issue 2, pp. 45-48, (Mar. – Apr. - 2013).
- [12]. Mohammad Tariqul Islam, Mohammed Nazmus Shakib, Norbahiah Misran, and Baharudin Yatim, "Analysis of Broadband Slotted Microstrip Patch Antenna," IEEE Trans. AP-1-4244-2136, 2008.
- [13]. Parminder Singh, Anjali Chandel, and Divya Naina, "Bandwidth Enhancement of Probe Fed Microstrip Patch Antenna," IJECCT, ISSN: 2249-7838, Vol. 3, Issue 1, January - 2013.
- [14]. Prabhaker Singh, G.S. Tripathi, and Amit Kumar Gupta, "Design of Small Size Extended T-Shaped Patch Microstrip Antenna," VSRD International Journals, e-ISSN: 2231-3346, p-ISSN: 2319-2232, Vol. No 3, 1 January-2013.
- [15]. Alak Majumder, "Design of an H-shaped Microstrip Patch Antenna for Bluetooth Applications," IJIAS, ISSN: 2028-9324, Vol. 3, No. 4, pp. 987-994, Aug. – 2013.