Design and Analysis of Directly Coupled Rectangular Element Microstrip Antenna for Ultra Wideband Applications

[1]Ashish Chaudhary, [2] Savya Sachi Mishra and [3] D. C. Dhubkariya

[1,2,3]*B.I.E.T., Jhansi, U.P., India.*

Abstract

This article, proposes directly coupled rectangular patch element rectangular Microstrip antenna for Ultra-wideband applications. The antenna consists of rectangular patch element coupled directly which provide a useful fractional bandwidth of more than 75 %(2.76-5.97 GHz). By direct coupling [1] the rectangular patch element additional resonances are excited and hence wider bandwidth is achieved at higher band. The proposed directly coupled Microstrip antenna is fed by 50Ω Microstrip feed line. Gain has been improved up to 4.21dBi, directivity 4.24dBi and efficiency 99.29%. The proposed antenna design and its performance are analyzed using IE3D software package of Zeeland. The measured results show that antenna offers a wide bandwidth covering all the 5.2/5.8 GHz WLAN, 3.5/5.5 Ghz WiMAX and 4 GHz C band.

Keywords: Direct coupling, Enhance bandwidth, Compact Microstrip(MS) Patch, Calculated ground plane, Gain, 50Ω Feed line.

I. INTRODUCTION

Microstrip patch antennas have drawn the attention of researchers due to its light weight, low profile, low cost and ease of integration with microwave circuit. But the major drawback of rectangular Microstrip antenna is its narrow bandwidth and lower gain. 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 [2, 3, 4, 5]. In the present work the bandwidth of Microstrip antenna is increased by direct coupling [1] and it is obtained that the bandwidth of direct coupled rectangular patch element rectangular Microstrip antenna is greater than simple rectangular Microstrip antenna. Directly coupled rectangular patch element rectangular Microstrip antenna with Microstrip line feed is shown in Figure1. The width of the Microstrip line was taken as 3 mm and the feed length as 3 mm. The patch is energized electromagnetically using 50Ω Microstrip feed line [6]. The proposed antenna has been designed on glass epoxy substrate ($\in_r$ = 4.4) [7]. 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 2.2 GHz. Different structures are simulated by using IE3D simulation software and it is obtained that rectangular patch element directly coupled gives highest bandwidth among all the structures that are simulated.

The frequency band (2.76-5.97 GHz) of proposed antenna is suitable for Ultra-wideband and broadband applications [8] such as military, wireless communication, satellite communication, global positioning system (GPS), RF devices, WLAN/WI - MAX application [9,5]. Broadband devices are mainly used in our daily lives such as mobile phone, radio, laptops and Microstrip patch antennas plays important role in these devices [10]. Ultra wide band (UWB) is an emerging technology that offers a new paradigm for the allocation and use of the radio spectrum [11,12]. UWB is a wireless technology for transmitting digital data at very high rates, using very low transmission power. UWB is well suited for short-range and high-speed data transmissions for wireless personal area network (WPAN) applications.

The paper is organized as follows, at first the antenna design is reported in section II. In section III, antenna specification, in section IV antenna design procedure, in section V Comparative Analysis followed by simulation results and discussion in section VI. Finally, a brief conclusion is presented in section VII.

II. ANTENNA DESIGN

The mathematical expression for computing the length and width dimension of the radiating rectangular Microstrip patch antenna are calculated as below [5, 13 and 14]

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

Where c is the velocity of light, ϵ_r is the dielectric constant of substrate, f_r is the antenna design frequency, W is the patch width, and the effective dielectric constant ϵ_{reff} is given as [15, 16]

$$\epsilon_{reff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{-\frac{1}{2}} \quad (2)$$

At h = 1.6mm

The extension length ΔL is calculates as [13, 14, 15]

$$\frac{\Delta L}{h} = 0.412\frac{\left(\epsilon_{reff}+0.3\right)\left(\frac{W}{h}+.264\right)}{\left(\epsilon_{reff}-.258\right)\left(\frac{W}{h}+0.8\right)} \quad (3)$$

By using the above mentioned equation we can find the value of actual length of the patch as [5, 12 and 14]

$$L = \frac{c}{2f_r\sqrt{\epsilon_{reff}}} - 2\Delta L \quad (4)$$

The length and the width of the ground plane can be calculated as [9, 13 and 14]

$$L_g = 6\text{h} + L \quad (5)$$

$$W_g = 6\text{h} + W \quad (6)$$

III. ANTENNA DESIGN SPECIFICATIONS

The design of proposed antenna is shown in figure1. The proposed antenna is designed by using glass epoxy substrate which has a dielectric constant ϵ_r = 4.4 and the design frequency is 2.4 GHz. Height of the dielectric substrate is 1.6 mm and loss tangent *tan*δ is 0.0013. Antenna is fed through a line feed of length 1 mm and width 2.5 mm which is energized by 50Ω Microstrip feed line. All the specifications are given in the table1 (all lengths are in mm and frequency in GHz).

Table 1: Antenna design specifications.

S.No.	Parameters	value
1.	Design frequency f_r	2.2
2.	Dielectric constant ϵ_r	4.4
3.	Substrate height h	1.6
4.	Patch width W	31
5.	Patch length L	41
6.	Ground plane width W_g	51
7.	Ground plane length L_g	41
8.	a	12.5
9.	b	5
10.	c	2.3
11.	d	10
12.	e	4
13.	f	6
14.	g	5
15.	h	18
16.	i	2.3

17.	j	5
18.	k	6
19.	l	10.2

IV. ANTENNA DESIGN PROCEDURE.

Dimensions of the proposed antenna are calculated very carefully using the equations 1, 2, 3, 4, 5 and 6. Design frequency is 2.2 GHz. For making a proposed direct coupled antenna four rectangular patch element each of same size is grown and these are directly coupled on other part of the rectangular patch element.

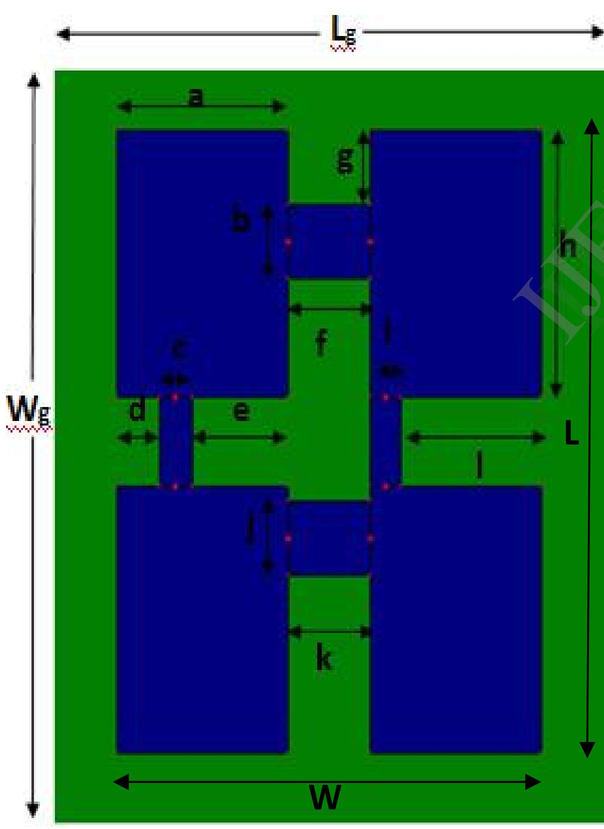
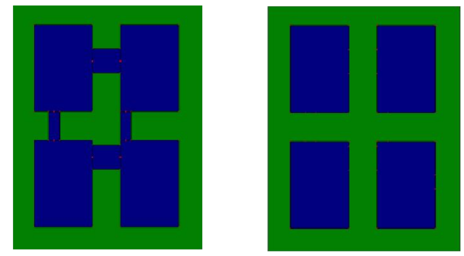


Figure 1: Geometry of proposed Microstrip antenna.

V: COMPARATIVE ANALYSIS.



a) b)

Figure 2: Two types structures: (a) direct coupled, (b) indirect or gas coupled.

Two different structures direct coupled antenna and indirect or gas coupled antenna as shown in Figure 2, are simulated and compared through Zeeland IE3D simulation software and their bandwidth are compared. By this computation work as shown in Figure 3, it is found that the bandwidth of rectangular Microstrip antenna with direct coupled is increased to a great extent.

Here it should be clear that all the dimensions of simulated antennas are same as in the proposed structure and line feed should also be at the same position with same dimensions.

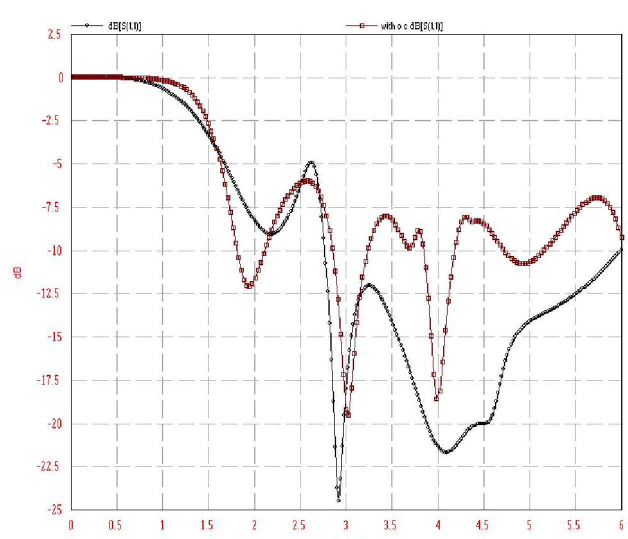


Figure 3: Comparison of return loss v/s frequency graph of with direct coupled and with out direct coupled structures.

VI. SIMULATION RESULT AND DISCUSSION

The narrow bandwidth of Microstrip antenna is one of the disadvantage that restrict its wide usage. In this article we tried to increase the bandwidth of rectangular Microstrip antenna by direct coupling [1] rectangular patch element. In this section simulations results for the return loss, VSWR, gain of the designed antennas are measured and presented. The frequency range of 0–6 GHz is used for simulation as WiMAX, WLAN and Broadband frequency bands lies in this range.

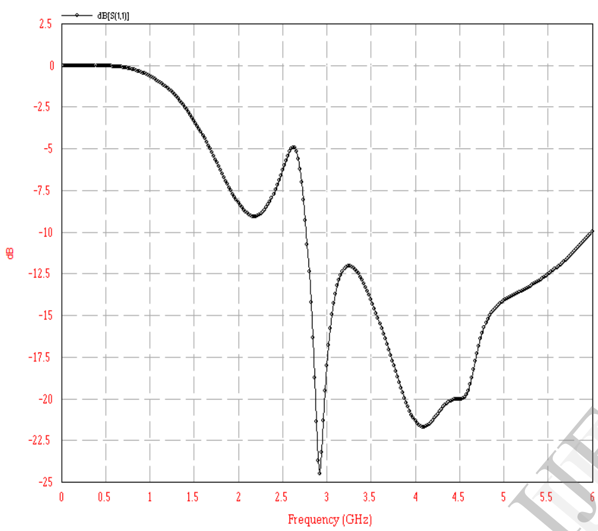


Figure 4: Return loss v/s frequency graph.

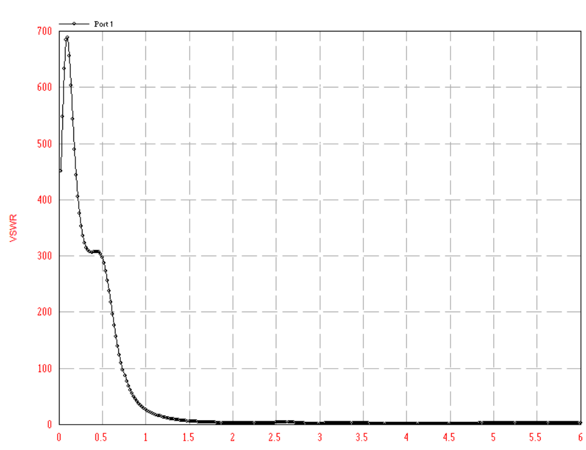


Figure 5: VSWR of proposed antenna

Figure 4, shows the simulated return loss of designed antenna. We observe that return loss for WLAN operating frequencies 2.4 GHz/5.2 GHz/5.8 GHz are -9 dB, -4 dB,-3dB respectively and for WiMAX operating bands 3.5 GHz/4.5 GHz/5.5 GHz are -14 dB, -18.77 dB, -12 dB respectively and for WLAN operating frequencies 5.2 GHz/5.8 GHz are -12.9 dB, -10 dB respectively. The return loss below -10 dB is sufficient for radiation. Therefore, from the simulation results we conclude that the proposed antenna exhibits wideband impedance bandwidth, the design is simulated using Zeeland IE3D version9 software. Figure 5, shows the VSWR of designed antenna. The VSWR of the antenna is in between 1 to 2 over the entire frequency band which shows that there is a proper impedance matching. It is observed that VSWR for WLAN operating frequencies 2.4 GHz/5.2 GHz/5.8 GHz are 2, 2, 2 respectively and for WiMAX operating bands 2.5 GHz/3.5 GHz/5.5 GHz are 3, 1.4, 1.6 respectively. The designed antenna exhibits wideband frequencies with VSWR < 2.2.

Gain Vs. Frequency graph of the microstrip square patch antenna is shown in Figure 6. The maximum gain of the antenna has been improved up to 5 dBi.

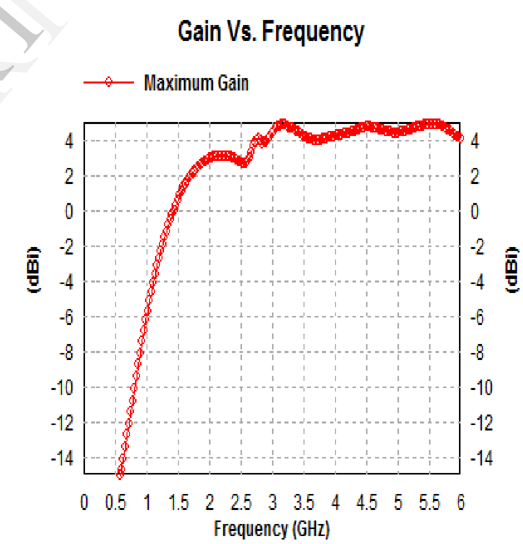


Figure 6: Gain vs. frequency plot.

This Gain designed antenna is more than that of rectangular microstrip patch antenna. Efficiency vs. frequency graph for designed rectangular element direct coupled microstip patch antenna is shown in Figure 7.

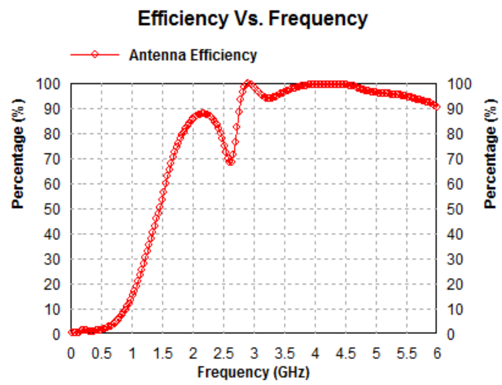


Figure 7: Efficiency graph of proposed antenna

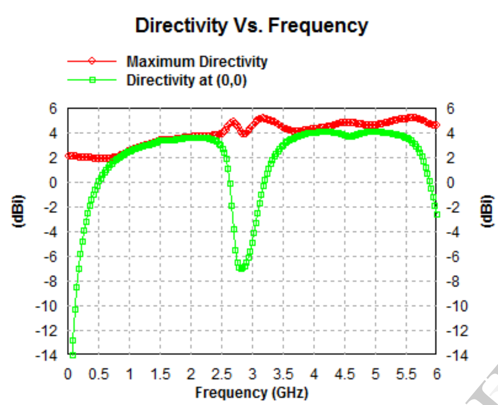


Figure 8: Directivity v/s frequency plot

Directivity Vs frequency graph is shown in Figure 8. Directivity of proposed antenna is improved to 5.39 dBi.

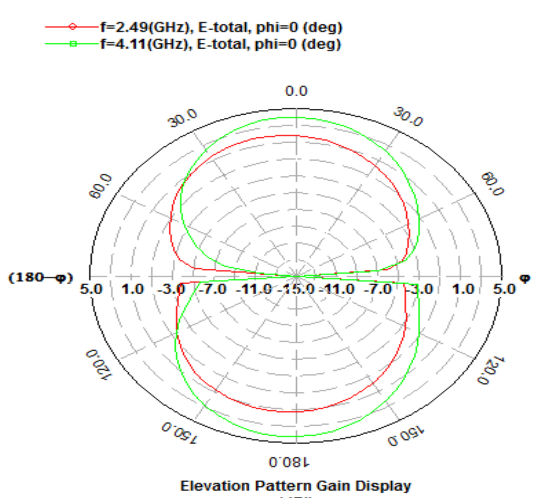


Figure 9: 2D radiation pattern of antenna

And the radiation pattern of the microstrip square patch antenna is shown in Figure 9.

VII. CONCLUSION

In this paper, a rectangular patch element microstrip antenna with single band characteristics and wide bandwidth capability for UWB applications is proposed. The antenna can operate from 2.79 to 6 GHz. By direct coupling the rectangular patch element with variable dimensions additional resonances are excited and hence much wider impedance bandwidth can be produced, especially at the higher band. The proposed Microstrip patch antenna provides band with 75.52%. The proposed antenna has been designed on glass epoxy substrate to give a maximum radiating efficiency of about 99.29% and high gain of about 4.24 dBi. It shows the designed antenna gives acceptable performance and thus can be used for UMTS-I, Wi-max, WLAN, and UMTS-II.

REFERENCES

[1] C.K. Wu, K.L. Wong, “Broadband microstrip antenna with directly coupled and gap-coupled parasitic patches”, Microwave and Optical Technology Letters, vol. 22, no. 5, pp. 348-349, 1999.

[2] Douglas, H. W., R. L. Haupt, and P. L. Werner, Fractal antenna engineering: The theory and design of fractal antenna arrays," IEEE Antennas and propagation Magazine, Vol. 41, No. 5, 37-59, 1999.

[3] H.A. Jang, D.O. Kim , and C. Y. Kim “ Size Reduction of Patch Antenna Array Using CSRRs Loaded Ground Plane”Progress In Electromagnetics Research Symposium Proceedings, KL MALAYSIA, March 27-30, 2012 1487.

[4] M. Gopikrishan, D. D. Krishna, C. K. Aanandan, P. Mohanan and K. Vasudevan, "Compact linear tapered slot antenna for UWB applications," Electronics Letters vol. 44, no. 20, pp. 1174-1176, 2008.

[5] 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.

[6] POZAR D.M., and SCHAUBERT D.H., “Microstrip Antennas, the Analysis and Design of Microstrip Antennas and Arrays”, IEEE Press, New York, USA, 1995.

[7] Rajesh Kumar, D. C. Dhubkarya, "Design and Analysis of Circular Ring Micro strip Antenna" GJRE (2011) Volume 11 Issue 1*: 11-14*.

[8] Kuo, Y. L. and K. L. Wong, Printed double- T monopole antenna for 2.4/5.2 GHz dual-band WLAN operations," IEEE Trans. Antennas Propag., Vol. 51, No. 9, 2187-2192.

[9] A.A. Abdelaziz,‖Bandwidth enhancement of Microstrip Antenna‖, Progress In Electromagnetic Research, PIER-63,pp. 311-317,2006.

[10] F. Abboud, et.al, ''New Determination of Resonant Frequency of Circular Disc Microstrip Antenna: Application to Thick Substrate,'' Electron. Lett.,Vol. 24,No.17, 1988,pp. 1104-1106.

[11] 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.

[12] M. T. Islam, M. N. Shakib, N. Misran and B. Yatim, "Analysis of Broadband Slotted Microstrip Patch Antenna", IEEE Trans. AP-1-4244-2136, 2008.

[13] Constantine A. Balanis, ''Antenna theory, Analysis and Design", John Wiley & Sons, Inc Hoboken, New Jersey, 2005.

[14] K. V. Rop, D. B. O. Konditi, H. A. Ouma and S. M. Musyoki, "Parameter optimization in design of a rectangular microstrip patch antenna using adaptive neuro-fuzzy inference system technique", IJTPE Journal, ISSN 2077-3528.

[15] T.Jayanthy, M.Sugadev, J.M. Ismaeel and G.Jegan, "Design and Simulation of Microstrip M- Patch Antenna with Double Layer", IEEE Trans., AP- 978-1-4244-2690-4444, 2008.

[16] 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.

[17] Chuan-Ling Hu, Chang-Fa Yang and Shun-Tian Lin, "A Compact Inverted-F Antenna to be Embedded in Ultra-thin Laptop Computer for LTE/WWAN/WI-MAX/WLAN Applications", IEEE Trans. AP-S/USRT,978-1-4244-9561, 2011.