Progress In Electromagnetics Research C, Vol. 18, 211–220, 2011

A COMACT MICROSTRIP PATCH ANTENNA FOR WIRELESS COMMUNICATION

U. Chakraborty

Department of ECE
Dr. B. C. Roy Engineering College
Durgapur-713206, West Bengal, India

S. Chatterjee

Department of ECE
Aryabhatta Institute for Engineering and Management, Durgapur
Panagarh, West Bengal, India

S. K. Chowdhury

Department of ECE, JIS College of Engineering
Phase-III, Block-A5, Kalyani, Nadia, West Bengal, India

P. P. Sarkar

USIC Department, University of Kalyani
Nadia, West Bengal, B-7/27, Kalyani, Nadia, Pin-741235, India

Abstract—A single feed compact rectangular microstrip antenna is presented in this paper. A triangular slot is introduced at the upper edge of the patch to reduce the resonant frequency. A small piece of triangular patch is added within the area of the triangular slot to improve the gain bandwidth performance of the antenna. The antenna size has been reduced by 46.2% when compared to a conventional square microstrip patch antenna with a maximum of 160 MHz bandwidth and −27.36 dB return loss. The characteristics of the designed structure are investigated by using MoM based electromagnetic solver, IE3D. An extensive analysis of the return loss, radiation pattern, gain and efficiency of the proposed antenna is shown in this paper. The simple configuration and low profile nature of the proposed antenna leads to easy fabrication and make it suitable for the

Received 12 October 2010, Accepted 10 December 2010, Scheduled 15 December 2010
Corresponding author: Samiran Chatterjee (samiran_engineer@rediffmail.com).

applications in Wireless communication system. Mainly it is developed to operate in the WiMax frequency range of 3.2–3.8 GHz.

1. INTRODUCTION

In recent years demand for small antennas on wireless communication has increased the interest of research work on compact microstrip antenna design among microwaves and wireless engineers [1–6]. To support the high mobility necessity for a wireless telecommunication device, a small and light weight antenna is likely to be preferred. For this purpose Compact Microstrip antenna is one of the most suitable application. The development of antenna for wireless communication also requires an antenna with more than one operating frequency.This is due to many reasons, mainly because there are various wireless communication systems and many telecommunication operators using various frequencies. Therefore one antenna that has multiband characteristic is more desirable than having one antenna for each frequency band. To reduce the size of the antenna one of the effective technique is cutting slot in proper position on the microstrip patch. The work to be presented in this paper is also a compact microstrip antenna design obtained by cutting a triangular slot on the patch but here in addition to the triangular slot a small piece of triangular patch is developed within the area of triangular slot to increase the return loss and gain-bandwidth performance of the antenna (Figure 2). To reduce the size of the antenna substrates are chosen with higher value of dielectric constant [7–9]. Our aim is to reduce the size of the antenna as well as increase the operating bandwidth. The proposed antenna (substrate with $\varepsilon_r = 4.4$) has a gain of 5.37 dBi and presents a size reduction of 46.2% when compared to a conventional square microstrip patch with a maximum bandwidth of 160 MHz. The simulation has been carried out by IE3D [10] software which uses the MOM method. Due to the Small size, low cost and low weight this antenna is a good candidate for the application of WiMax technology in the frequency range of 3.2–3.8 GHz.

2. ANTENNA STRUCTURE

The configuration of the conventional antenna is shown in Figure 1. The antenna is a 20 mm × 20 mm square patch. The dielectric material selected for this design is an FR4 epoxy with dielectric constant $(\varepsilon_r) = 4.4$ and substrate height $(h) = 1.6$ mm. Co-axial probe feed of radius 0.5 mm with a simple ground plane arrangement is used at point (2.5, −4.5) where the centre of the patch is considered at point (0, 0).

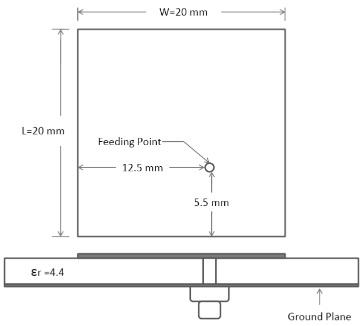


Figure 1. Antenna 1 configuration.

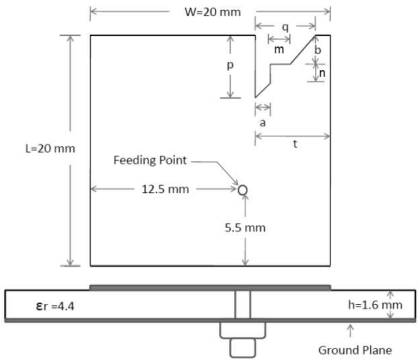


Figure 2. Antenna 2 configuration.

Table 1. Optimal parameter values of the antenna.

Parameter	p	q	a	b	t	m	n
Values (mm)	4	4	0.25	2.5	6.75	0.75	0.75

Figure 2 shows the configuration of antenna 2 which is designed with a similar substrate. The antenna is also a 20 mm × 20 mm square patch. A triangular slot of length 'p' and width 'q' is created on the rectangular patch. A small triangular patch is added within the area of triangular slot which is placed 'a' and 'b' distance apart from the side of the triangular slot. The location of coaxial probe-feed (radius = 0.5 mm) is also shown in Figure 2 as well.

3. SIMULATED RESULTS AND ANALYSIS

In this section, various parametric analysis of the proposed antenna are carried out and presented. Several parameter of the antenna have been investigated to improve bandwidth, gain and return loss performance of the antenna. Optimal parameter values of the antenna are listed in Table 1.

The simulated return loss of the conventional antenna (antenna 1) and the proposed antenna (antenna 2) are shown in Figure 3 and Figure 4 respectively.

In conventional antenna return loss found of about −17.15 dB at 5.015 GHz and −19.3 dB at 7.84 GHz and corresponding bandwidth is 30 MHz and 80 MHz respectively. Comparing Figure 3 and Figure 4 it

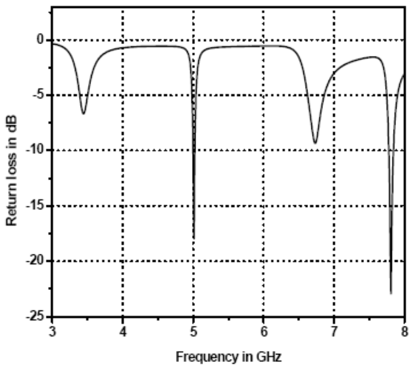


Figure 3. Simulated return loss of the antenna 1.

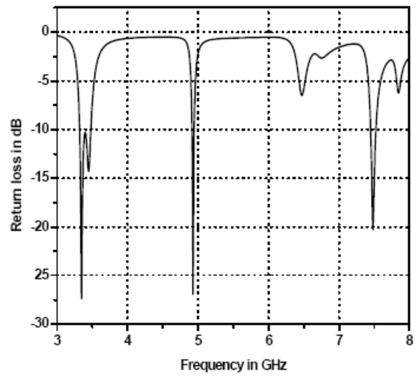


Figure 4. Simulated return loss of the antenna 2.

may be observed that for the conventional antenna (Figure 3) there is practically no resonant frequency at around 3.4 GHz with a return loss of around −6 dB. For the proposed antenna there is a deep resonant frequency at around 3.4 GHz where the return loss is as high as −27 dB. Hence a significant improvement of frequency reduction is achieved in antenna 2 with respect to the conventional antenna1 structure. Due to the presence of slot at the edge of the patch of antenna2 multi frequency operation is obtained with large values of frequency ratio. For antenna 2 return losses −27.36 dB is obtained at 3.345 GHz, −26.91 dB at 4.93 GHz and −20.27 dB at 7.48 GHz and corresponding 10 dB bandwidth is 160 MHz, 30 MHz and 80 MHz respectively.

3.1. Effect of Parameter 'p' and 'q' on the 1st Operating Band of the Proposed Antenna

For the fixed values of 'q', 'a', 'b', 'm' and 'n' the length of the slot 'p' is varied and simulation results are displayed in Figure 5. If the values of 'p' is made greater than 4 mm (Table 1), a portion of return loss curve goes above the −10 dB line within the 1st operating band of the antenna 2. As a result the band is divided into two different bands below −10 dB line. By this way size reduction of the antenna may be increased in lieu of bandwidth. When 'p' is less than 4 mm, maximum return loss value is increased but the operating bandwidth is decreased. As the resonant frequency shifts towards a higher value, size reduction of the antenna is also reduced.

For the fixed values of 'p', 'a', 'b', 'm' and 'n' the width of the slot 'q' is varied and simulation results are displayed in Figure 6. If the

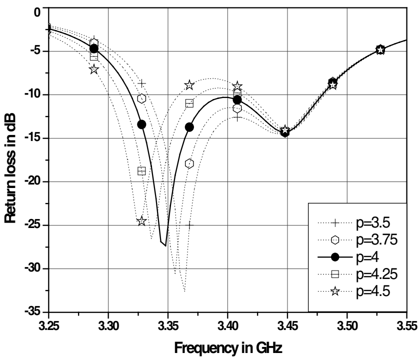


Figure 5. Simulated return loss for different values of p.

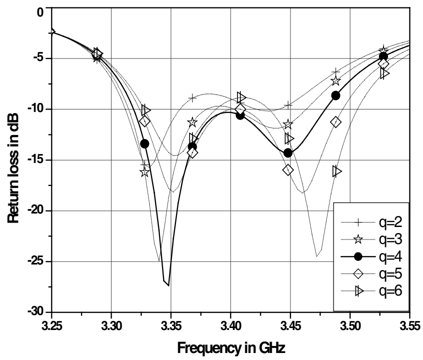


Figure 6. Simulated return loss for different values of q.

values of 'q' are made less than 4 mm (Table 1), a portion of return loss curve goes above the -10 dB line within the 1st operating band and the result is large reduction of bandwidth. When 'q' is increased than 4 mm, return loss curve goes above the -10 dB line in the middle of the operating band. It also observed that the resonant frequency shifts towards the higher value, so size reduction of the antenna also reduced with the reduction of operating bandwidth. From the Figure 6, it is clear that higher value of bandwidth with higher value of size reduction is possible only for $q = 4$ mm.

3.2. Effect of Parameter 't', 'm' and 'n' on the 1st Operating Band of the Proposed Antenna

For the fixed values of 'p', 'q', 'a', 'b', 'm' and 'n' the position of the slot from the right side of the rectangular patch 't' is varied and simulation results are displayed in Figure 7. If the values of 'p' is increased than 6.75 mm (Table 1), resonant frequency shifts towards a lower value but a large portion of the return loss curve within the operating band goes above the -10 dB line and the bandwidth is decreased in large amount. By this way size reduction of the antenna also may be increased in lieu of bandwidth. For 't' less than 6.75 mm, operating bandwidth is gradually decreased. As the resonant frequency shifts towards the higher value, size reduction of the antenna also reduced.

For the fixed values of 'p', 'q', 'a', 'b', 'm' and 'n' the length and width of the added patch is varied and simulation results are displayed in Figure 8. As indicated in Figure 8 the best values of m & n are 0.75 mm each.

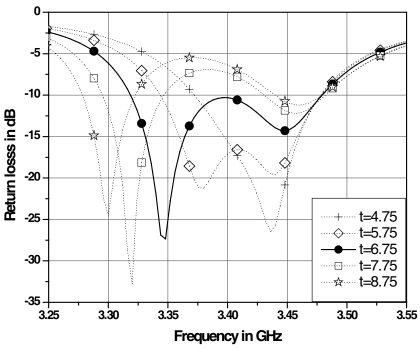


Figure 7. Simulated return loss for different values of t.

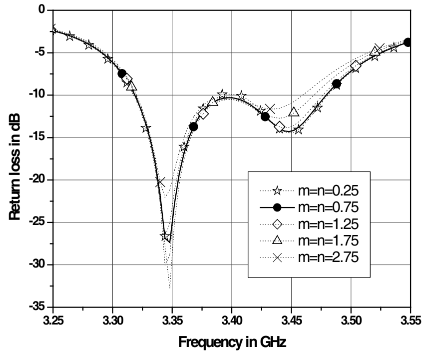
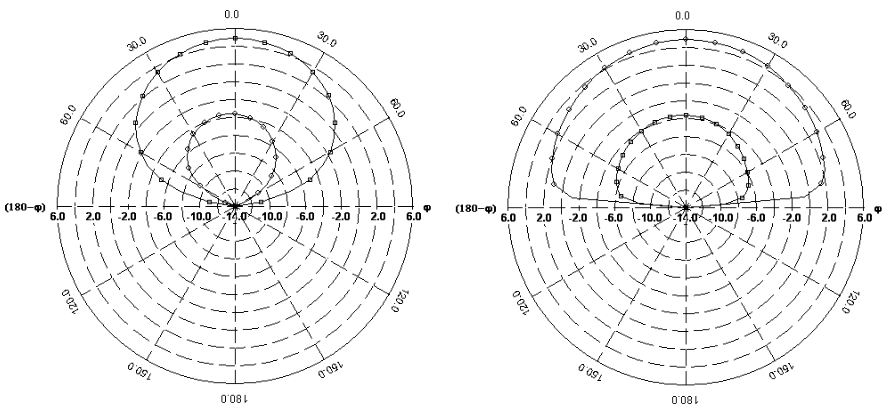


Figure 8. Simulated return loss for different values of 'm' and 'n' on the 1st band.



(a) *E*-field pattern (b) *H*-field pattern

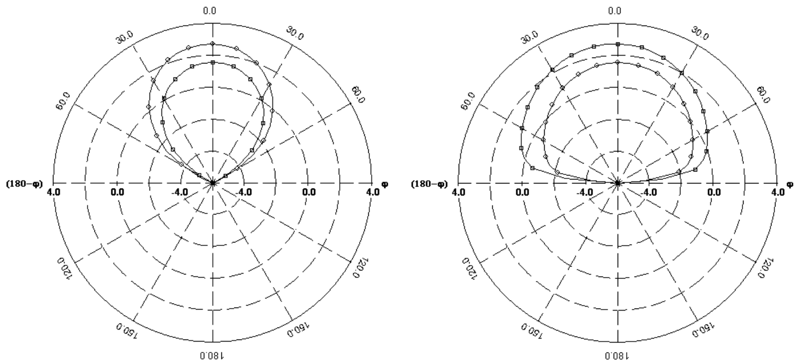
Figure 9. Simulated radiation pattern at 3.345 GHz.

3.3. Simulated Radiation Pattern

The simulated E plane and H plane radiation patterns for antenna 2 are shown in Figures 9–11.

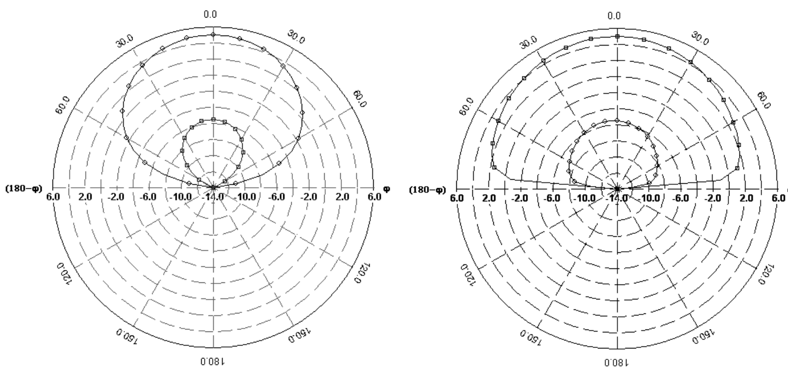
Figure 12 shows the total field gain versus frequency plot for the antenna 2. It is observed that for the first band antenna gain is about 5.37 dBi and for 5 GHz band, 6.5 GHz band and 7.48 GHz band antenna gain lies above 3.7 dBi.

Efficiency of the antenna 2 (radiating efficiency and antenna efficiency) with the variation of frequency is shown in Figure 13. It is found that for the lower band of operation efficiency of the antenna 2 is about 72–80%.



(a) *E*-field pattern (b) *H*-field pattern

Figure 10. Simulated radiation pattern at 3.4 GHz.



(a) *E*-field pattern (b) *H*-field pattern

Figure 11. Simulated radiation pattern at 3. 45 GHz.

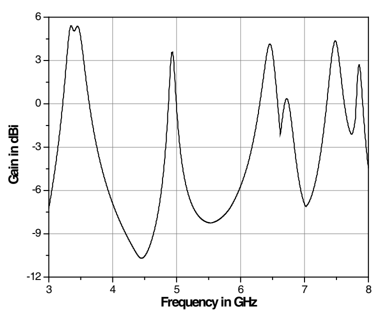


Figure 12. Total field gain versus frequency plot for the antenna 2.

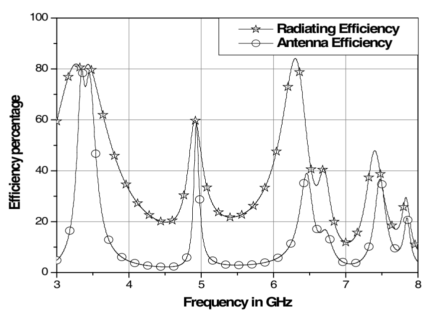


Figure 13. Efficiency versus frequency plot for the antenna 2.

4. EXPERIMENTAL RESULTS AND DISCUSSION

The prototype of the antenna 1 (conventional) and antenna 2 (proposed antenna) was fabricated and tested, which are depicted in Figures 14 and 15. All the measurements are carried out using Vector Network Analyzer (VNA) Agilent N5 230A.

The measured return losses of the antenna are illustrated in Figures 16–17. The comparisons of the measured return loss with the simulated are shown in Figures 18(a) and 18(b). The discrepancy between the measured and simulated results is due to the effect of improper soldering of SMA connector or fabrication tolerance. However, the measured bandwidth is relatively equal to the simulated impedance bandwidth; 160 MHz which shows a reasonable agreement through the entire band.

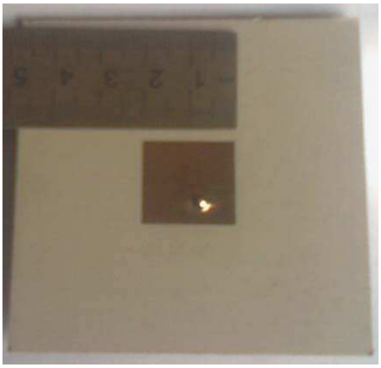


Figure 14. Antenna 1.

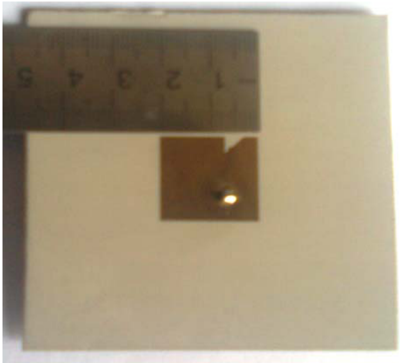


Figure 15. Antenna 2.

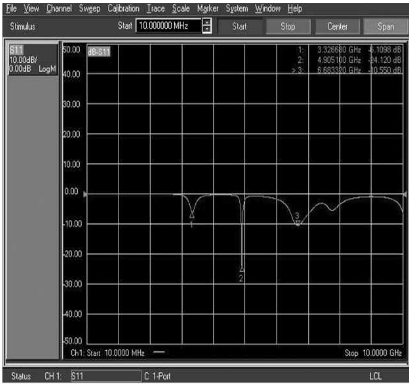


Figure 16. Measured return loss of antenna 1.

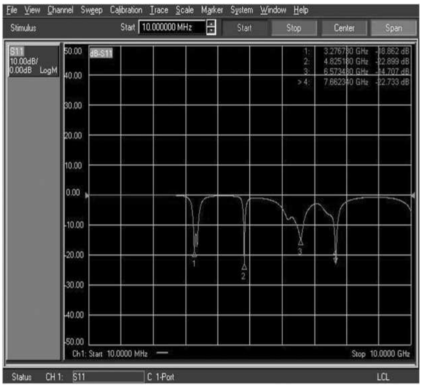
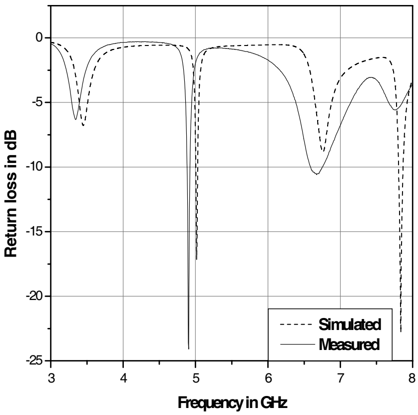
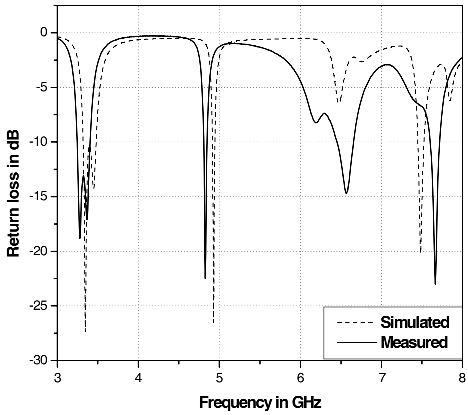


Figure 17. Measured return loss of antenna 2.



(a)



(b)

Figure 18. Comparison between measured and simulated return losses (a) antenna 1, (b) antenna 2.

5. CONCLUSION

A single feed single layer triangular slot microstrip antenna has been proposed in this paper. It is shown that the proposed antenna can operate in three frequency bands. Triangular slot reduced the size of the antenna by 46.2% and addition of a small triangular patch within the area of the triangular slot increase the bandwidth upto 160 MHz with a return loss of −27.36 dB, absolute gain about 5.37 dBi and 3 dB beamwidth of 137°. Efficiency of antenna has been achieved about 78–80% for the lower band, 60% for the middle band and 40% for the higher band of operation. Alteration of the location of the triangular slot can more reduce the lower resonant frequency but divide the lower band into two different bands with lower value of bandwidth. An optimization between size reduction and bandwidth enhancement is maintained in this work.

ACKNOWLEDGMENT

We acknowledge gratefully the financial support for this work provided by AICTE (India) in the form of a project Entitled “DEVELOPMENT OF COMPACT, BROADBAND AND EFFICIENT PATCH ANTENNAS FOR MOBILE COMMUNICATION”. The measurement facility provided by Prof. Santanu Das of BESU, Shibpur, Howrah is gratefully acknowledged.

REFERENCES

1. Wu, J.-W., H.-M. Hsiao, J.-H. Lu, and S.-H. Chang, "Dual broadband design of rectangular slot antenna for 2.4 and 5 GHz wireless communication," *IEE Electron. Lett.*, Vol. 40, No. 23, November 11, 2004.
2. Raj, R. K., M. Joseph, C. K. Anandan, K. Vasudevan, and P. Mohanan, "A new compact microstrip-fed dual-band coplaner antenna for WLAN applications," *IEEE Trans. Antennas Propag.*, Vol. 54, No. 12, 3755–3762, December 2006.
3. Zhang, Z., M. F. Iskander, J.-C. Langer, and J. Mathews, "Dual-band WLAN dipole antenna using an internal matching circuit," *IEEE Trans. Antennas and Propag.*, Vol. 53, No. 5, 1813–1818, May 2005.
4. Sarkar, I., P. P. Sarkar, and S. K. Chowdhury, "A new compact printed antenna for mobile communication," *2009 Loughborough Antennas & Propagation Conference*, Loughborough, UK, November 16–17, 2009.
5. Jan, J.-Y. and L.-C. Tseng, "Small planar monopole antenna with a shorted parasitic inverted-L wire for wireless communications in the 2.4, 5.2 and 5.8 GHz bands," *IEEE Trans. Antennas and Propag.*, Vol. 52, No. 7, 1903–1905, July 2004.
6. Danideh, A., R. S. Fakhr, and H. R. Hassani, "Wideband co-planar microstrip patch antenna," *Progress In Electromagnetics Research Letters*, Vol. 4, 81–89, 2008.
7. Bahl, I. J. and P. Bhartia, *Microstrip Antennas*, Artech House, Dedham, MA, 1980.
8. Hammerstad, E. O., "Equations for microstrip circuit design," *Proc. Fifth European Microwave Conf.*, 268–272, September 1975.
9. Balanis, C. A., *Advanced Engineering Electromagnetic*, John Wiley & Sons., New York, 1989.
10. Zeland Software Inc., IE3D: MOM-Based EM Simulator, Web: http://www.zeland.com.