Pattern Reconfigurable Antenna using Key-shaped Monopoles for WiMAX Application

Sweta Agarwal and Manoj Kumar Meshram
Indian Institute of Technology (BHU), Varanasi
mkmeshram.ece@iitbhu.ac.in

Abstract

In this paper, omnidirectional pattern reconfigurable antenna is designed using key-shaped monopole antennas. It consists of two identical key-shaped monopoles with partial ground plane. The proposed antenna provides pattern reconfigurability in the two different planes YZ and XZ with the help of two PIN diodes. The overall dimension of the proposed antennas is 40x40x1.6 mm^3. It covers the 10dB impedance bandwidth of 64.32% (2.88 to 5.61 GHz), which covers a wide range of applications.

Keywords– ***key-shaped monopole antenna, pattern reconfigurable antenna, PIN diodes.***

1. Introduction

In the growing era, reconfigurable antennas deal a great attention. Reconfiguring the pattern of the antennas is the best method to efficiently utilize the available spectrum. A pattern reconfigurable antenna has attractive features such as increased channel capacity, enhanced radiation coverage, and beam sweeping capability for point-to-multipoint communications [1]-[5]. The pattern reconfigurable antenna has the ability to change its patterns dynamically without affecting the other characteristics [6]. In addition, the reconfigurable pattern antenna can also avoid the interference of noise environment by directing null positions of its radiation pattern which provides larger coverage by redirecting the main beam [7].

In the literatures, various pattern reconfigurable antennas using monopoles have been proposed [8]-[14] .In [8], four beam pattern reconfigurable antennas were proposed in which pattern reconfigurability was achieved by changing the states of the four PIN diodes. The PIN diodes were connected between the central patch and monopoles. It has 10dB impedance bandwidth of 25.7% (3.32–4.3 GHz). In [9], monopole-like and bore sight pattern reconfigurable antenna was proposed. The proposed antenna was fed by the co-planar waveguide (CPW). By changing the switching states of the diodes connected on the monopole, it operated as slot antenna which gave reconfigured radiation pattern by bore sight pattern to its perpendicular direction. In [10], radiation pattern reconfigurable antenna using monopole loop for fitbit flex wristband was proposed. In [11], explained the change of radiation pattern of monopole antenna to pattern of dipole antenna by controlling the switch states. In [12], with the use of four diodes and two parasitic elements the radiation pattern was reconfigured in omnidirectional pattern to two directional patterns with opposite directions. In [13], microstrip fed pattern and polarization reconfigurable compact truncated monopole antenna was presented. The pattern was reconfigured with polarization in the orthogonal planes. Asymmetric coplanar strip fed pattern reconfigurable antenna was proposed in [14].

In this paper, orthogonally placed two key-shaped monopoles for pattern reconfigurability are proposed. The proposed antennas are connected with a common feed through two PIN diodes. By controlling the switching state of the PIN diodes, the omnidirectional patterns in the two different planes XZ and YZ with gain of approximate 2.5dBi are achieved. This makes antenna structure more simple and low in cost. The proposed antenna covers a wide range of applications in the operating frequency range. It covers IEE802.16 WiMAX (3.3-3.6GHz; 5.25-5.82GHz), IEEE802.11a wide local area network (5.15-5.35GHz) and ETSI HiperLan/2(5.15-5.35 GHz; 5.47-5.725GHz).

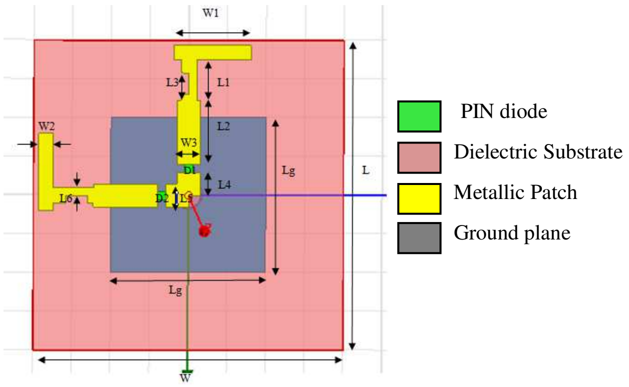
2. Antenna Design and Analysis

2.1. Antenna configuration

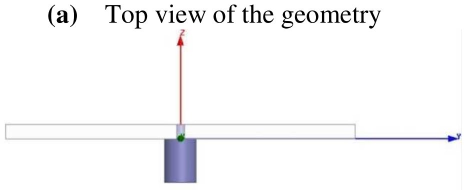
The configuration of the proposed pattern reconfigurable antenna is shown in Figure 1. It comprises of partial square-shaped ground plane, two PIN diodes as switch, and two key- shaped identical monopoles placed orthogonal to each other at the top side of the dielectric substrate which are connected to a common feed through two PIN diode. The proposed antenna is designed using 1.6 mm thick FR-4 substrate having dielectric constant 4.4 and loss tangent 0.02. The overall size of the antenna is 40x40 mm^2. In the proposed antenna, two PIN diodes are used to reconfigure the pattern in two different plane YZ and XZ plane. The DC bias circuit is used to bias the PIN diode**.** The pattern reconfigurability of is achieved by changing the diode state as ON/OFF. It is noted that at a time one diode is kept ON while other diode kept OFF.

2.2 Parametric Study

To optimize the antenna geometry, parametric study is carried out using ANSYS HFSS (High Frequency Structure Simulator) [15]. The square-shaped partial ground plane is chosen to maintain the symmetry with orthogonally placed microstripline fed monopoles. The length (Lg) of the ground plane is optimized for the wider impedance bandwidth by keeping other shape parameters constant as given in Table 1. The variation of S_{11} with frequency for different length of the ground plane is plotted in Figure 2. It is observed that with the increase of L_g impedance bandwidth increases at certain length after that it deteriorates. Various shape parameters of the antenna is optimized by varying one parameter at a time and keeping all other parameters at fixed value. The S_{11} is severely affected by varying W1, L4, and L6 of the monopole which helps to decide the lower frequency of the band as well as impedance bandwidth of the antenna. The variation of S_{11} with frequency for different values of W1, L4, and L5 are plotted in Figure 3, 4, and 5 respectively. Since, other shape parameters do not affect significantly therefore they are not shown here for brevity. The optimisation shape parameters are shown in the Table 1.



(a) Top view of the geometry



(b) Side view of the geometry

Figure 1. Configuration of the proposed antenna

Table1. Dimensions of Antenna after optimization

Parameters	Values (mm)	Parameters	Values (mm)
L	40	L5	3
W	40	L4	3
Lg	20	L6	1
L1	5.1	W1	10
L2	8.3	W2	2
L3	3	W3	3

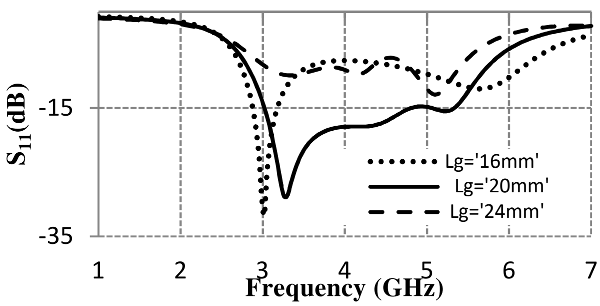


Figure 2. Variation of S_{11} with frequency for different lengths of the ground plane.

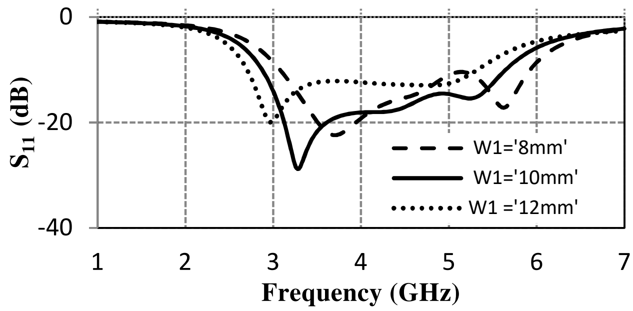


Figure 3. Dependency of S_{11} on W1

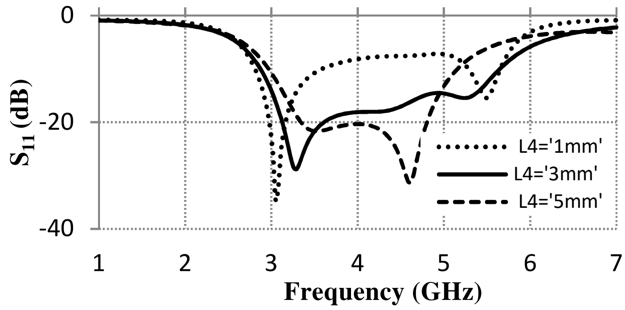


Figure 4. Dependency of S_{11} on centre patch

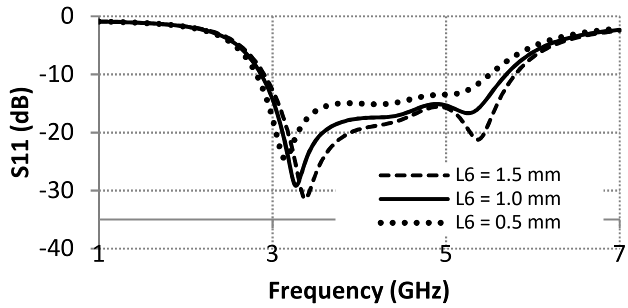


Figure 5. Effect of notch present on monopole

3. Results and Discussion

After performing the parametric study, on various parameters such as size of ground plane, length of horizontal arm, centre patch etc., it is observed that the optimized dimensions given in Table 1 gives 10dB impedance bandwidth of 64.32% from 2.88 GHz to 5.61 GHz for both cases when diode D1 ON and D2 OFF and vice versa. In both cases the antenna resonates at same frequency band from 2.88 to 5.61 GHz.

Figure 6(i) and (ii) shows the current distribution at frequency 3.44 GHz at both modes when only one diode is ON and other remains OFF, respectively. It shows that the when diode D1 is ON the maximum current is flowing in the x-direction thus the radiation pattern covers the YZ plane with null along the x-axis. Similarly due to same structure present in the horizontal direction, when diode D2 is ON the maximum current is flowing in the y-direction thus the radiation pattern covers the XZ-plane with null along the y-axis.

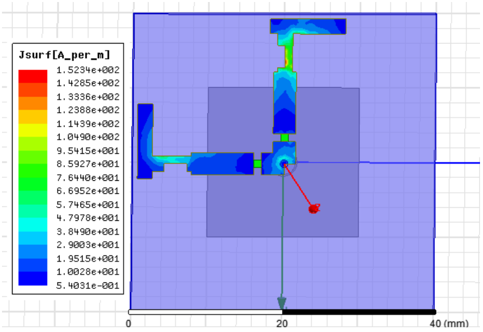


Figure 6(i). Current distribution at frequency 3.44 GHz when diode D1 is ON and D2 is OFF.

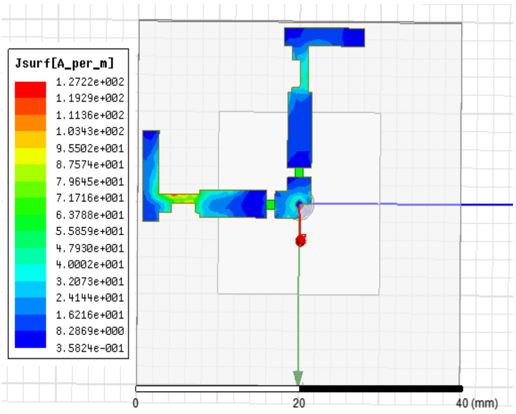
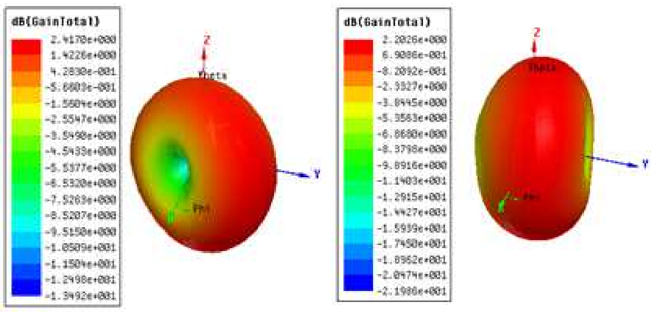


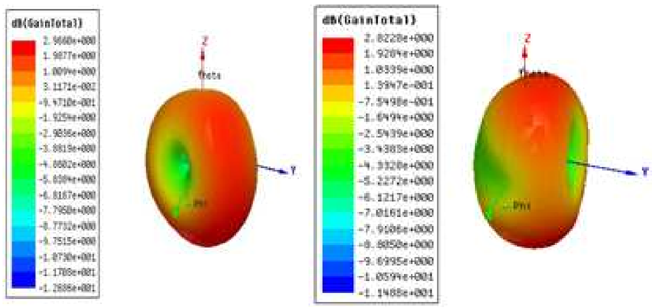
Figure 6 (ii) . Current distributions at frequency 3.44 GHz when diode D2 is ON and D2 is OFF

Figure 7 (i) to (iii) shows that the 3-D radiation patterns of the proposed antenna at 3.5 GHz, 4.13 GHz, and 5.04 GHz, respectively for two different switching states of the diode. It is observed that the monopole antenna gives the omnidirectional patterns throughout the frequency band. It is also observed that by changing the switching states of diode D1 and D2 alternately, the radiation pattern of the proposed antenna changes from YZ- plane to XZ- plane. This shows that after changing the switching states of D1 and D2 the direction of radiation patterns is changing with approximate same gain.



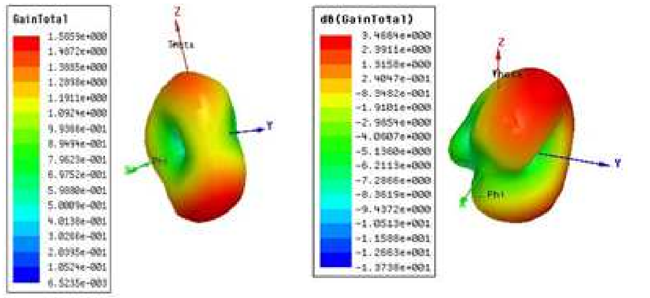
(a) D1 is ON (b) D2 is ON

(i) 3.5 GHz



(a) D1 is ON (b) D2 is ON

(ii) 4.13 GHz



(a) D1 is ON (b) D2 is ON

(iii) 5.04 GHz

Figure 7. 3-D radiation patterns of the proposed antenna.

4. Conclusion

In this paper, two identical key-shaped monopole patterns reconfigurable antennas are presented. It reconfigured the radiation pattern in XZ- and YZ-planes. The antenna covers wide band of frequency 2.88 to 5.64 GHz having 10dB impedance bandwidth of 64.32%.

5. References

1. J. T. Bernhard, *Reconfigurable Antennas*, London, U.K.: Morgan & Claypool,, 2007.

2. M. C. Tang, B. Y. Zhou, and R. W. Ziolkowski, “Low-profile, electrically small, Huygens source antenna with pattern-reconfigurability that covers the entire azimuthal plane,” *IEEE Transactions Antennas Propagation* vol. 65, no. 3, March 2017, pp. 1063–1072.

3. C. G. Christodoulou, Y. Tawk, S. A. Lane, and S. R. Erwin, “Reconfigurable antennas for wireless and space applications,” *Proc. IEEE*, vol. 100, no. 7, , July 2012, pp. 2250–2261.

4. N. Nguyen-Trong, L. Hall, and C. Fumeaux, “A frequency- and pattern reconfigurable center-shorted microstrip antenna,” *IEEE Antennas Wireless Propagation Letters.*, vol. 15, 2016, pp. 1955–1958.

5. L. Ge, K. M. Luk, and S. C. Chen, “360° beam-steering reconfigurable wideband substrate integrated waveguide horn antenna *IEEE Transactions Antennas Propagation.*, vol. 64, no. 12, Dec. 2016, pp. 5005–5011.

6. B.Z. Wang, S.Q. Xiao, Y.Y Bai and G.M. Zhang," Researches on pattern reconfigurable antenna and its application in phase array," in *Proc.Int. Workshop Antenna Technology,* March 2011, pp. 46-49.

7. S.H Chen, J.S Row and K.L. Wong, "Reconfigurable Square -Ring Patch Antenna with Pattern Diversity", *IEEE Transactions Antennas Propagation*, vol.55, no.2, feb 2007, pp.472-475.

8. G. Jin,M. Li, D. Liu, And G. Zeng, "A Simple Four-Beam Reconfigurable Antenna Based on Monopole", *IEEE Access*, volume 6, 2018. pp 30309-30316.

9. I. Lim,S.Lim," Monopole -Like and Boresight Pattern Reconfigurable Antenna ", IEEE *Transactions Antennas Propagation*, vol.61, no.12, December 2013, pp.5854-5859.

10. C. M Lee and C. W. Jung, "Radiation Pattern Reconfigurable Antenna Using Monopole Loop for Fitbit Flex Wristband", *IEEE Antennas and Wireless Propagation letters, Vol* 14, 2015, pp. 269-272.

11. W.S Kang, J.A. Park and Y.J Yoon, "Simple Reconfigurable Antenna with Radiation Pattern", *Electronics Letters*, Vol. 44, No.3, 31 Jan 2008.

12. T. Aboufoul, C. Parini, X. Chen and A. Alomainy, "Pattern -Reconfigurable Planner Circular Ultra-Wideband Monopole Antenna", *IEEE Transactions Antennas Propagation*, vol.61, no.10, oct 2013, pp.4973-4980.

13. S. Raman, P. Mohanan, N. Timmons and J. Morrison, "Microstrip- Fed Pattern -and Polarization - Reconfigurable Compact Monopole Antenna", *IEEE Antennas and Wireless Propagation Letters,*Vol.12,2013, pp-710-713.

14. P. Ashkarali, S. Sreenath, R.K. Raj and C.K. Aanadan "Asymmetric Coplaner Strip Fed Pattern Reconfigurable Antenna", *European Journal of Advanced in Engineering and Technology*,2015,2(6) ,pp 43-46.

15. ANSYS: http://www.ansys.com/products.