ISSN (online) : 2277-5390
ISSN (Print) : 2277-5382

Design of slotted H-shaped patch antenna with dumbbell shaped DGS for 3.5 GHz WiMAX applications

E. Aravindraj[1], Dr. K. Ayyappan[2]

Department of Electronics and Communication Engineering, Rajiv Gandhi College of Engineering and Technology, Puducherry, India.
aravindraj1794@gmail.com[1], ayyappan_ece@rgcet.ac.in[2]

Abstract

Objectives: To improve the antenna parameters for 3.5GHz WiMAX frequency by introducing slotted H-shaped patch with Dumbbell (H) shaped Defective Ground Surface (DGS).
Methods/ analysis: In wireless communication, microstrip patch antennas are playing a vital role in various wireless applications. Worldwide Interoperability for Microwave Access (WiMAX) has been widely used in voice, data, video and internet access. WiMAX can able to provide above 100Mbps data rates.
Findings: The proposed antenna has symmetrical properties and has been designed by a dumbbell (H) shaped DGS on Flame Retardant-4 (FR-4) substrate fed up by microstrip feeding. The dimension of the designed antenna is 29×35×1.56mm. It radiates at 3.5GHz WiMAX frequency.
Improvements/Applications: The designed antenna offers improved antenna parameters for 3.5 GHz WiMAX applications.

Keywords: Microstrip patch antenna, slotted H-shaped patch, Dumbbell (H) shaped defective ground space, FR-4 substrate, WiMAX.

1. Introduction

Microstrip patch antennas are widely used for many wireless applications. It has major advantages such as low cost, easy fabrication, low profile, compactness, easy installation etc [1]. But these antennas have major disadvantages like low efficiency, poor polarization purity. Microstrip patch antenna systems have become more essential for the next-generation communication systems where several wireless communication application [2]. Etching slots are introduced to obtain optimized reflection coefficient in the design of the antenna [3-5]. Here, the designed antenna will offer operating frequency of 3.5 GHz for WiMAX application. WiMAX technologies to provide wireless high-speed Internet and network connections. It is a wireless broadband technology that offers flexibility. WiMAX gives up to 1 Gbps in static stations. It provides platform for internet access at-homes, offices, schools, work places, etc., or mobile Internet access across a huge space [6].

FR-4 substrates are widely used in antenna design because of its low cost, medium dielectric constant and loss tangent value. It has high efficiency compared to substrate materials and easily available in the market. Thick substrate with lower dielectric constant had been proposed to increase the bandwidth and antenna efficiency. On the other hand, thin substrate with higher dielectric constant had been proposed to minimize antenna size, but it decreased antenna bandwidth and efficiency [7, 8]. So an optimization between bandwidth, efficiency and antenna size had to be done for its fascinating applications.

A defect had been etched on the ground plane to introduce a DGS [9]. By introducing the DGS in the microstrip patch antenna (MPA) will reduce the size of the patch with increased bandwidth and reduced return loss [10]. Advanced Design System is the electronic design automation software for designing antenna with its circuits and has high speed digital applications. The most efficient shaped antenna, surface current and surface wave loss concepts are used that state the less the antenna incorporates surface current, the less the surface wave loss will be and the better the efficiency of the antenna will be resulted [11]. In this work, a microstrip patch antennas designed for 3.5 GHz WiMAX applications is presented.

Antenna design

The antenna design has a slotted microstrip patch of 20 x 26 x 0.04 mm as in Figure 1 placed on a FR-4 substrate 29 x 35 x1.56 mm, with a dielectric constant of 4.4 and a loss tangent of 0.02. The ground plane has a dumbbell (H) shaped DGS as in Figure 2 and Figure 3. The detailed design parameters are explained below.

Figure 1. Design of H-shaped microstrip patch antenna

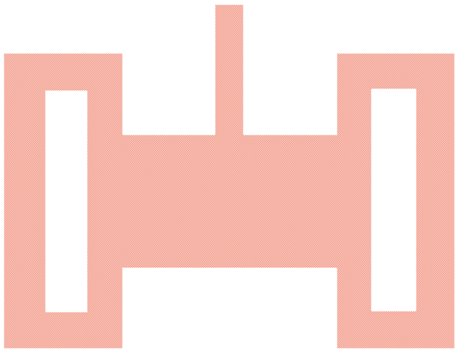
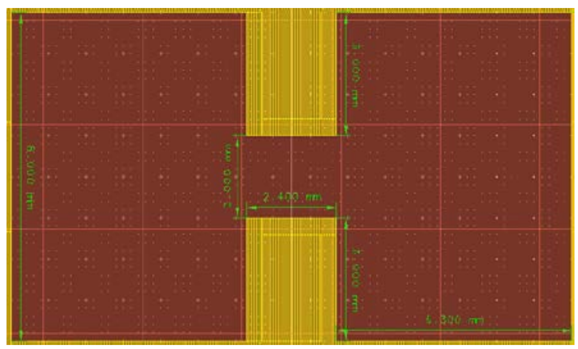


Figure 2. Positioning of the Dumbbell (H) shaped DGS structure for 3.5 GHz

Figure 3. Dimensions of the Dumbbell (H) shaped defect for 3.5 GHz



Slotted H-shaped microstrip patch

The overall view of the slotted H-shaped patch is shown in Figure 1. The final optimized geometry was obtained through simulations with the software Advanced design software (ADS). The antenna operating at the 3.5GHz frequency band was achieved using an H- shaped radiator with defective ground surface and the etching slots in the 20 x 26 mm^2 patch. This makes the H-shaped antenna to be more efficient compared to other antennas [3].Thus the reflection loss will be comparatively low and the user can utilize the radiation pattern efficiently without any distortion. The designed MPA for 3.5GHz frequency for WiMAX applications can be efficiently utilized. This shaped antenna will offer improved antenna parameters compared to other shaped antennas.

2. Methodology

FR-4 material with relative dielectric constant (ε_r) of 4.4 for the substrate and annealed copper (Cu) are used for the patch, ground plane and microstrip feeding line of each antenna. The operating frequency (f_r) is considered as 3.5 GHz and the height of the dielectric substrate (h) is considered as 1.56 mm for the designed MPA. Patch width (W), effective dielectric constant (ε_{reff}), patch length extension (ΔL), effective patch length (L_{eff}), patch length (L), ground plane width (W_g), ground plane length (L_g), substrate width (W_s) and substrate length (L_s) of the antennas are calculated for of (f_r) and (ε_r)as in [12, 13].

Calculation of Patch Width (W):

$$W = \frac{C}{2f_r}\sqrt{\frac{2}{\varepsilon_r}} \tag{1}$$

 ISSN (online) : 2277-5390
ISSN (Print) : 2277-5382

Calculation of Effective Dielectric Constant (ε_{reff}):

$$\varepsilon_{reff}=\frac{\varepsilon_r+1}{2}+\frac{\varepsilon_r-1}{2}(1+\frac{12h}{W})^{-1/2} \quad (2)$$

Calculation of Patch Length Extension (*ΔL):*

$$\Delta L=0.412h(\frac{\varepsilon_{reff}+0.3}{\varepsilon_{reff}-0.258})(\frac{\frac{W}{h}+0.264}{\frac{W}{h}+0.8}) \quad (3)$$

Calculation of Effective Patch Length (L_{eff}):

$$L_{eff}=\frac{c}{2f_r\sqrt{\varepsilon_{reff}}} \quad (4)$$

Calculation of Patch Length (L):

$$L = L_{eff}-2\Delta L \quad (5)$$

Calculation of Ground Plane Width (W_g), Ground Plane Length (L_g), Substrate Length(L_s), Substrate width (W_s):

$$W_s = W_g = 6h + W \quad (6)$$

$$L_s = L_g = 6\,h + L \quad (7)$$

Dumbbell (H) shaped DGS

The H-shaped patch antenna with DGS is placed at a distance of 16 mm from the vertical side and 18 mm from the horizontal side of the ground plane. The ground plane is placed on the FR4 substrate to generate the operating frequency of 3.5 GHz. The defective ground plane will allow the antenna to produce increased directivity, gain and efficiency and the etching slots improve the bandwidth and return loss. As in table 1, a ground plane consisting of 29 x 35 mm metal patch. The dimensions of the DGS and the position of the antenna structure to the DGS were further optimized to provide the best characteristics at the intended frequency of 3.5 GHz. Parametric studies are provided in Figures 4-11 which conveys the effect of the design parameters on the antenna characteristics. Figure 1 shows the structure of the metal patch on the substrate. It is noticed that the reflection coefficients change only slightly, while the antenna characteristics change significantly. Hence Figure 4 shows the best radiation characteristics using the 29 x 35 mm^2 configuration. By the influence of Dumbbell shape, the horizontal and vertical position of the antenna ground plane is presented in Figure 2. Finally, the dimensions of the DGS described in Figure 3, which shows a large influence on the AR characteristics at 3.5 GHz.

Table 1. Specification of the H-shaped MPA

Antenna Parts	Parameters (symbols)	Values in mm
Substrate	Length (L_s)	29
	Width (W_s)	35
	Height (h)	1.56
Patch	Length (L_p)	20
	Width (W_p)	26
	Thickness (t)	0.04
Feed line	Width (W_f)	2.4
Ground plane	Length (L_g)	29
	Width (W_g)	35
	Thickness (t)	0.04

ISSN (online) : 2277-5390
ISSN (Print) : 2277-5382

Figure 4. Return loss of the MPA

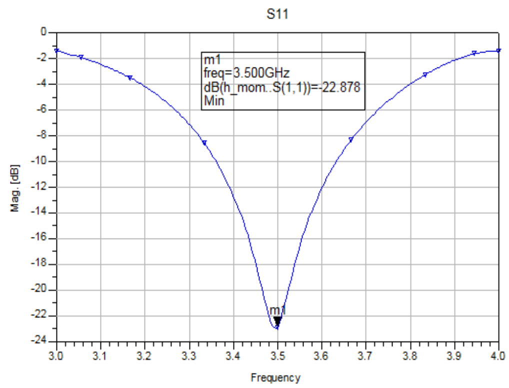


Figure 5. Smith chart of the MPA

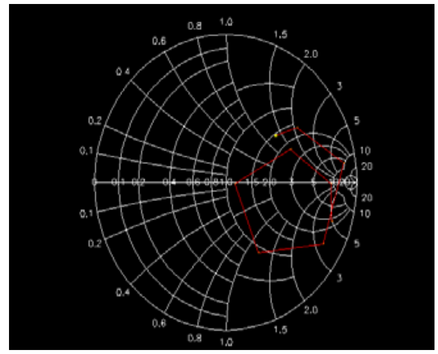


Figure 6. Bandwidth of the antenna for 3.5 GHz

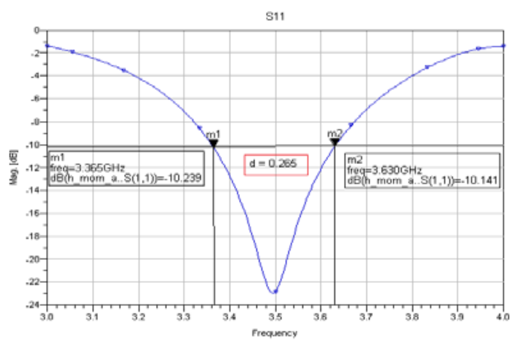


Figure 7. Gain and directivity of the MPA

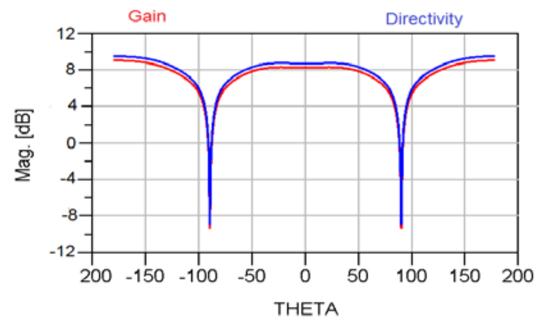


Figure 8. Radiation pattern of the MPA

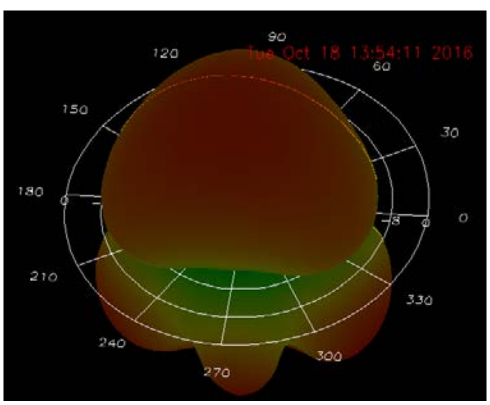


Figure 9. Efficiency of the MPA

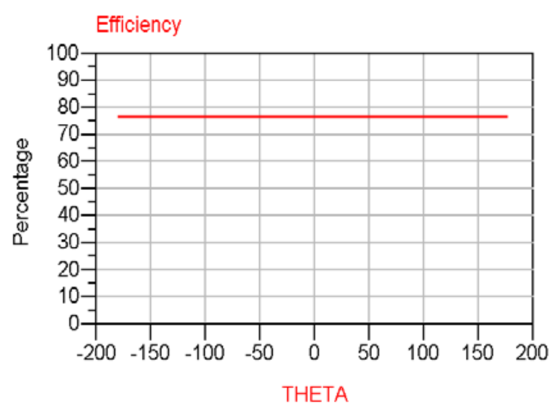


Figure 10. Impendence of the MPA

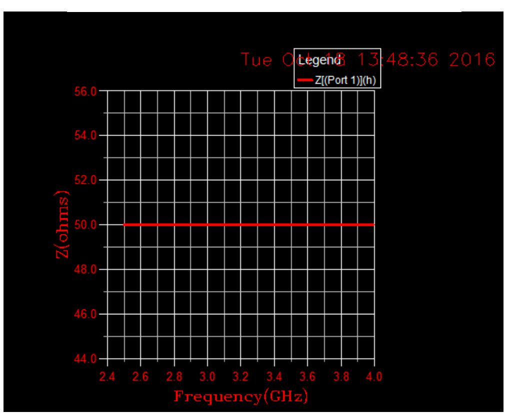
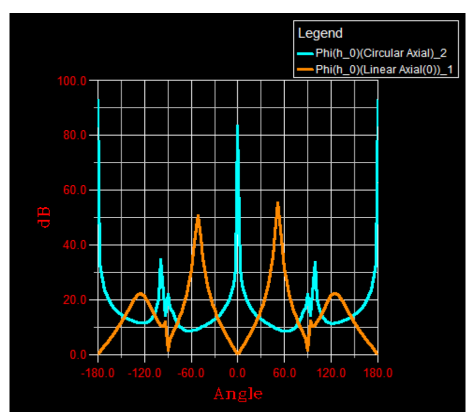


Figure 11. Circular and linear axial of the MPA



ISSN (online) : 2277-5390
ISSN (Print) : 2277-5382

3. Simulation results

The designed slotted H-shaped microstrip patch antenna with dumbbell shaped DGS has a patch and a ground plane size of 20 x 26 mm^2 and 29 x 35 mm^2 respectively. The antenna substrate with the DGS is placed on the H-shaped antenna. The simulated antenna parameters such as return loss, bandwidth, radiation pattern, input impedance, smith chart, gain, directivity, efficiency and axial ratio are shown in Figures 4-11 respectively. Simulated results show good agreement with all the antenna parameters of the other shape of antennas. The antenna provides a maximum bandwidth at -10dB which is sufficient for a good impedance matching the Table 2 shows that the antenna has successfully achieved the outputs for 3.5 GHz (3.365-3.630 GHz) WiMAX applications. The simulation has been made using the ADS software which provides a platform in measuring the parameters of the antenna.

Table 2. Simulated results of slotted H-shaped microstrip patch antenna with dumbbell (H) shaped DGS

Frequency	Gain (dB)	Directivity (dB)	VSWR	Return loss (dB)	Bandwidth	Efficiency
3.5 GHz	8.674	9.533	1.1270	-22.878	265 MHz	77%

4. Conclusion

The H-shaped microstrip patch antenna design with dumbbell (H) shaped DGS for 3.5 GHz frequency is designed for WiMAX application. The H-shaped antenna produces improved antenna parameters such as directivity and gain of 86.5%and 78% respectively with preferable return loss of -22.878 and has a good impedance matching (50 ohms). It has a VSWR value of 1.127 and the bandwidth is 265 MHz (3.365 – 3.630 GHz) for 3.5GHz WiMAX frequency. The Efficiency offered by the antenna is 77% with relatively high gain, wider bandwidth and expected return loss reduction. Thus, this antenna which is used for WiMAX applications brings potential benefits in terms of coverage, power consumption and bandwidth efficiency.

5. References

1. Makhluk Hossain Prio, Md. Mamun Ur Rashid, Liton Chandra Paul, Ajay Krishno Sarkar. Total efficiency comparison of different shaped microstrip patch antennas having defected ground structure. In *2015 International Conference on Electrical & Electronic Engineering (ICEEE), Bangladesh*, 2015; 265-268.
2. V. Palanisamy, R. Garg. Rectangular ring and H-shaped microstrip antennas–Alternatives to rectangular patch antenna. *Electronics Letters.* 1985; 21(19), 874-876.
3. R. Cai, S. Lin, G. Huang, J. Wang. Simulation and experimental research on the multi-band slot-loaded printed antenna.In *2010 IEEE 12th International Conference on Communication Technology, China,* 2010; 500-503.
4. Jianling Chen, Kin-Fai Tong, Allann Al Armaghany, Junhong Wang. A dual band dual polarization slot patch antenna for GPS and Wi-Fi applications. *IEEE Antennas and Wireless Propagation Letters*. 2015; 15, 406-409.
5. Merbin John, B.Manoj, G.Jagadish Chandran. Design of a slotted rectangular microstrip patch antenna operated in ISM band using RT-duroid substrate. *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering.*2016; 5(S4), 15-21.
6. Antonidos G. Sarigiannidis, Petros Nicopolitidis, Georgios. Papadimitriou, Panagiotis G. Sarigiannidis, Malamati D. Louta. On the use of learning automata in tuning the channel split ratio of WiMAX networks. *IEEE systems journal*. 2015; 9(3), 651-663.
7. Punita Mane, S.A. Patil, P.C. Dhanawade. Comparative study of microstrip antenna for different substrate material at different frequencies. *International Journal of Emerging Engineering Research and Technology*. 2014; 2(9), 18-23.
8. Kiran Jain, Keshav Gupta. Different substrates use in microstrip patch antenna-A survey. *International Journal of Science and Research.* 2014, 3(5), 1-2.
9. L.H. Weng, Y.C. Guo, X.W. Shi, X.Q. Chen. An overview on defected ground structure. *Progress in Electromagnetic Research*, 2008; 7, 173-189.
10. C.A. Balanis. Antenna Theory: Analysis and design. 2^{nd} (edn), John Wiley & Sons: US. 2005.

11. T.V. Hoang, H.C. Park. Very simple 2.45/3.5/5.8 GHz triple-band circularly polarised printed monopole antenna with bandwidth enhancement. *Electronics Letters.*2014; 50(24), 1792-1793.
12. S. Tignath, L. Shrivastava. Design and analysis of E shaped effected ground antenna using MATLAB. *International Journal of Advanced Research in Computer Science &Technology*. 2013; 1(1), 27-29.
13. A.S.U. Constantine, A. Balanis. Antenna Theory: analysis and design. 3rd (edn), John Wiley& Sons: US. 2005; 811-882.

The Publication fee is defrayed by Indian Society for Education and Environment (iSee). www.iseeadyar.org

Citation:

E. Aravindraj, Dr.K. Ayyappan.Design of slotted h-shaped patch antenna with dumbbell shaped DGS for 3.5 GHz wimax applications. *Indian Journal of Innovations and Developments.* 2016; 5 (2), February.