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A Microstrip Patch Antenna with Defected Ground Structure(DGS) for WiMAX and WLAN Applications

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Abstract: ***A rectangular microstrip patch antenna with defected ground structure with E-shaped and square shaped slot on the patch is proposed here. The proposed antenna design consists of H-shaped defect on the ground plane. The complete antenna system is constructed on 45.4mm X 45.4mm X 1.6mm, FR-4 substrate with dielectric constant of 4.4 and substrate height of 1.6mm. The antenna mainly works in 4-6 GHz band. The various characteristics parameters of the antenna like return loss, voltage standing wave ratio, impedance, gain, bandwidth and radiation pattern are studied. The antenna is simulated using high frequency structured simulator software , simulated*** S_{11}***< -10dB, in the entire operating range of 4-6 GHz.The proposed antenna design is mainly focused for the wireless applications and is suitable for IEEE 802.11 WLAN standards in the bands 5.2/5.8 GHz and WiMAX standards in the bands at 5.5 GHz. In this design microstrip line feeding is used.***

Keywords: Defected ground structure, E-shaped slot, Microstrip patch antenna, WiMAX, WLAN.

I. INTRODUCTION

The main focus of the next generation wireless system is higher speed networking services. Microstrip patch antenna is mainly used for various wireless communication system because of various advantages such as compact size, light weight, low cost, easy to fabricate. The antenna can be more efficiently used by improving the various parameters such as high input impedance, bandwidth and gain efficiency.

Antenna miniaturization, improvement of the bandwidth, higher input impedance and efficiency are the main parameters for the improvement of the antenna performance [1-2]. In the recent years, need of the wireless broadband communication has increased which demands service quality, security, integrity, and increased throughput for the wireless local area networks [2]. By using the DGS technique WLAN band can be easily obtained in the compact antenna system.DGS is analyzed in terms of its superior properties, that enables the user to easily design the antenna system for the wireless communication purposes [5,6,9]. DGS suppress the surface waves and it is a unique technique which is used to decrease the size of the antenna and also it increases the bandwidth, therefore it mainly increases the performance of the antenna system. This technique is efficient for cost also because it is more convenient that certain design can operate easily with single element without using multiple antenna elements [8]. The shielded current distribution on the ground plane is disturbed by the defect size as well as dimension of the defect [7]. The shielded current distribution disturbance affects the input impedance and the flow of the current of antenna. It also controls the excitation and propagation of the electromagnetic waves through the substrate [9].

Here a rectangular microstrip patch antenna with defected ground structure and line feed is proposed. The main objective of the design is to reduce the antenna size and the idea of design is taken from the broadband antenna and thus the antenna is suitable for the 4-6 GHz frequency band. Rectangular shaped patch and defected ground structure technique is used because of the high input impedance. In this design double layer substrate antenna with line feeding is used to achieve the multiband operation of the antenna for wireless applications which mainly coves the upper band of the WLAN.

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II. ANTENNA GEOMETRY

The proposed antenna design is constructed on FR-4 substrate of dielectric constant of 4.4 and substrate thickness of 1.6mm.

The various antenna dimensions are obtained by using the below formulas and then they are optimized using the HFSS simulation software. The overall size of the antenna is 45.4mm X 45.4mm X 1.6mm. In the proposed design rectangular shaped patch is used. On the patch E- shaped and square shaped slots are constructed. The design also consists of H-shaped defect on the ground plane.

The substrate dielectric constant ϵ_r is based on the dielectric material. A substrate of 4.4 dielectric constant and height of 1.6 mm is taken for the presented microstrip patch antenna. Various parameters are required for the preferred design, with dielectric constant and substrate thickness are set as constant values to acquire preferred impedance matching of the rectangular microstrip patch antenna.

The various antenna dimensions are calculated using the formulas shown below.

Calculations of the Length of the Patch(L_p) –

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2}\left[1 + 12\,\frac{h}{Wp}\right]^{-1/2} \quad (1)$$

$$L_{eff} = \frac{c}{2 f_r \sqrt{\epsilon_{eff}}} \quad (2)$$

$$\Delta L = 0.412h \frac{(\epsilon_{eff}+0.3)(\frac{W_p}{h}+0.264)}{(\epsilon_{eff}-0.258)(\frac{W_p}{h}+0.8)} \quad (3)$$

$$L_p = L_{eff} - 2\Delta L \quad (4)$$

Calculations of the Width of the Patch(W_p)-

$$W_p = \frac{c}{2 f_r \sqrt{\frac{(\epsilon_r+1)}{2}}} \quad (5)$$

Where,

f_r is the resonant frequency.

W_p is width of the patch.

L_p is length of the patch.

h is the thickness of the substrate.

ϵ_r is the substrate dielectric constant.

c is the speed of light : $3*10^8$ m/s

Width of the ground plane (W_g) and length of the ground plane (L_g) are calculated by using the below formulas [1]:-

$$W_g = 6h + W_p \quad (6)$$

$$L_g = 6h + L_p \quad (7)$$

or

$$W_g = 12h + W_p \quad (8)$$

$$L_g = 12h + L_p \quad (9)$$

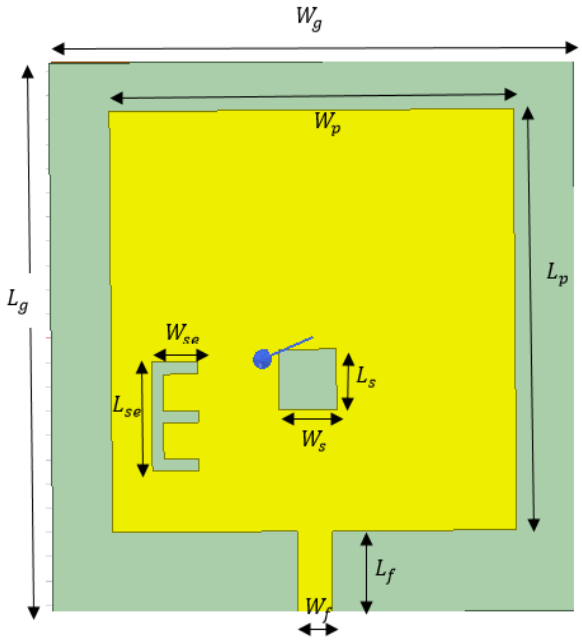

Fig .1. (a) Top View of the Proposed Antenna Design

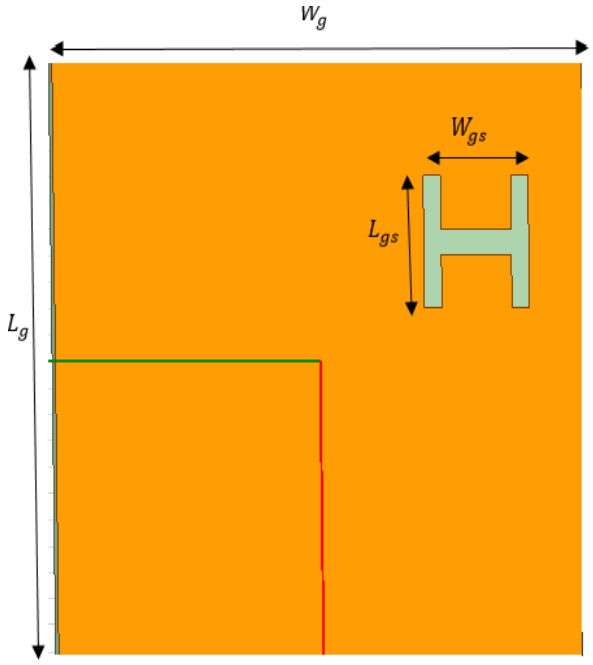

Fig .1. (b) Bottom View of the Proposed Antenna Design

Table 1: Optimized Dimensions of the Microstrip Antenna

Parameter Description	Dimensions of the Parameters
Substrate of antenna	FR-4
Dielectric Constant of substrate, ϵ_r	4.4
Substrate thickness, h	1.6 mm
Input impedance of antenna, Z_o	50 Ω
Width of the ground , W_g	45.4mm
Length of the ground, L_g	45.4mm
Width of the patch, W_p	35 mm
Length of the patch, L_p	34.7 mm
Width of the microstrip feed , W_f	3 mm
Length of the microstrip feed, L_f	6.7mm
Square slot side	5 mm
E-shaped slot length	9 mm
E- shaped slot width	4 mm
Length of the substrate	45.4 mm
Width of the substrate	45.4 mm
Width of H-shaped defect	9 mm
Length of the H-shaped defect	10mm

The various parameters and dimensions of those parameters are shown in Table1. These parameters are calculated based on the above formulas and then these parameters are optimized using the HFSS software. Based on these dimensions the antenna is designed and then is simulated for obtaining the various results.

III. SIMULATION RESULT AND ANALYSIS

The simulation of the proposed antenna is done by Ansoft HFSS simulation software and the results of the simulation of the antenna are shown in the below figures.

A.Return Loss Analysis

Return loss is mainly the loss of power in the signal reflected back by a discontinuity in the transmission line. The return loss should be as low as possible. The proposed design return loss is -24.49 dB at frequency 5.27 GHz, -27.48 dB at frequency of 5.5 GHz and and -28.46dB at a frequency of 5.8 GHz.

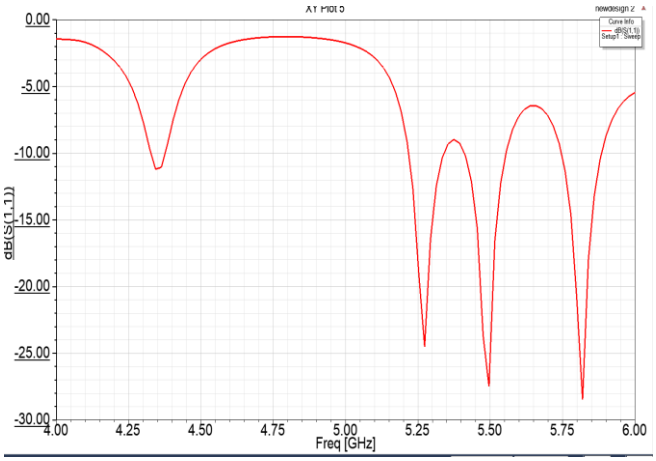

Fig. 2. Return Loss Plot of the Proposed Antenna

B. Voltage Standing Wave Ratio(VSWR) Analysis

It is a measure of how efficiently power transmitted, from any source through a transmission line into the load. The VSWR of the antenna should be less than 2. The proposed design VSWR is observed as 1.12, 1.08, 1.07 at frequencies of 5.27GHz, 5.5 GHz and 5.8 GHz respectively.

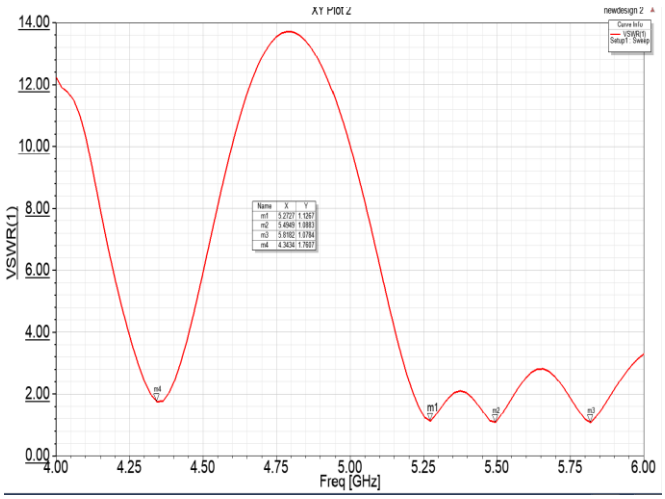

Fig. 3. VSWR Plot of the Proposed Antenna

C.Bandwidth Analysis

It is mainly the frequency ranges through which the antenna can operate correctly. The bandwidth of the proposed antenna is 120MHz ,140 MHz and 140 MHZ at frequencies of 5.27 GHz, 5.5 GHz and 5.8 GHz respectively.

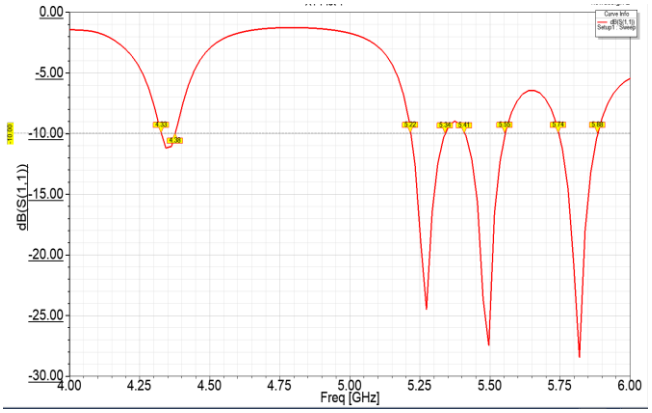

Fig. 4. Bandwidth Plot of the Proposed Antenna

D.Impedance Analysis

The antenna with a real input impedance of 50 ohm is said to be perfectly matched. The fig 5 shows the input impedances of the antenna at 5.27 GHz, 5.5 GHz and 5.8 GHz frequencies which is very close to 50 ohms.

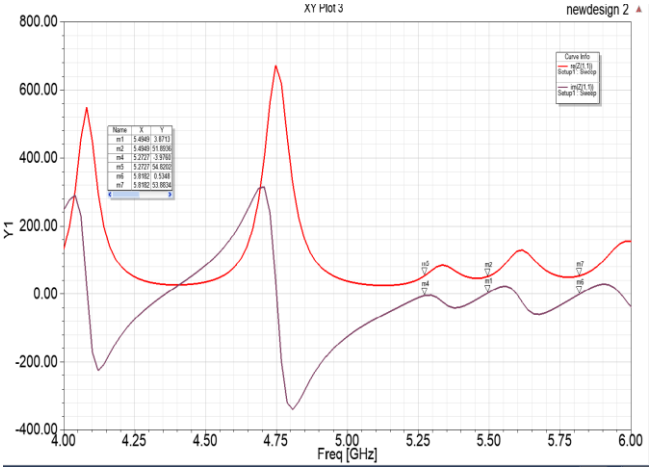

Fig. 5. Input Impedance Plot of the Proposed Antenna

E.Radiation Pattern

Radiation pattern plot of the proposed antenna is shown in the Fig 6.

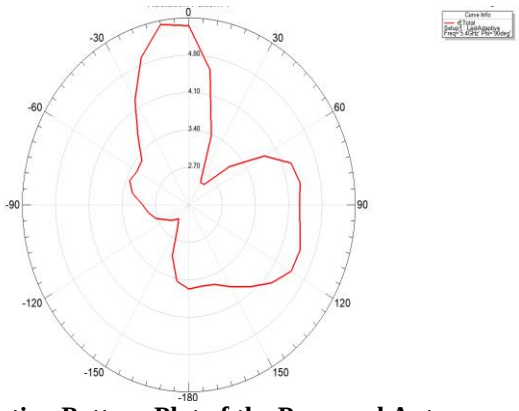

Fig. 6. Radiation Pattern Plot of the Proposed Antenna

F. 3D Polar Plot

The polar plot of the proposed design is shown in the Fig.7.

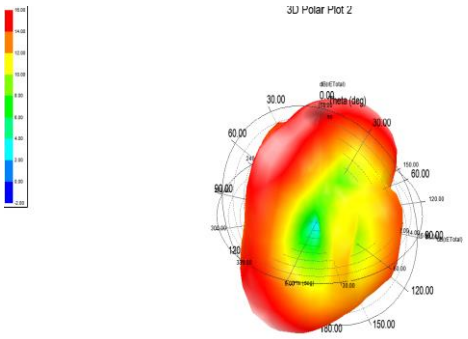

Fig .7. 3D Polar Plot of the Proposed Antenna

IV. CONCLUSION

A rectangular microstrip patch antenna with defected ground structure and E-shaped and square shaped slot on the patch is proposed in this paper. The H-shaped defect is taken as a defective ground structure. By using the slots and defect the various parameters of the antenna like return loss, VSWR, bandwidth, gain and efficiency are improved. The antenna resonates at 5.27GHz, 5.5 GHz and 5.8 GHz. The frequencies 5.27GHz and 5.8 GHz are used for WLAN and 5.5 GHz is used for WiMAX applications. Thus the antenna mainly focused on wireless applications. The proposed design return loss is -24.49 dB at frequency 5.27 GHz, -27.48 dB at frequency of 5.5 GHz and and -28.46dB at a frequency of 5.8 GHz.The VSWR is below 2 at all above frequencies. Bandwidth of the antenna is also improved by using the DGS and 4.53 dB of gain is also obtained.

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Pragya Jain was born in Bhopal, Madhya Pradesh, India, in 1993.She completed her Bachelor of Engineering in Electronics and Communication from B.T. Institute of Research and Technology, Sagar, Madhya Pradesh, India in year 2015. She started her Master of Engineering degree in Microwave Engineering from Jabalpur Engineering College, Jabalpur, Madhya Pradesh in 2017. She presented her research work on microstrip antenna with defected ground structure(DGS) for ISM Band in International Conference on Electronics, Materials Engineering and Nano Technology(IEMENTech) in 2019 IEEE Conference.

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