Design Of Slotted H-Shaped Patch Antenna For 2.4 GHz WLAN Applications

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Abstract—**Microstrip patch antennas are widely used in various wireless applications such as Wireless local area network (WLAN). WLAN is capable of providing maximum data transfer rate of 600 Mbps. The proposed antenna design has a slotted H-shaped patch and dumbbell (H) shaped Defected Ground Structure (DGS) on Flame Retardant-4 (FR-4) substrate with the microstrip feeding technique which radiates at 2.4GHz WLAN frequency. The overall size of the antenna is 39×47×1.56 mm. The simulation results are obtained using Advanced design software (ADS) which offers improved antenna parameters such as gain, directivity, bandwidth, return loss, voltage standing wave ratio (VSWR) and impedance matching.**

Keywords- Microstrip patch antenna, slotted H-shaped patch, Dumbbell (H) shaped DGS, FR-4 substrate and WLAN.

I. INTRODUCTION

Microstrip patch antennas (MPA) have achieved great extend in mobile communication, satellites, WLAN and WiMAX application. It has various advantages such as low profile, compactness, easy fabrication, easy installation, low cost etc. [1]. But these antennas have major disadvantages like low efficiency, poor polarization purity etc. Microstrip patch antenna systems are more essential for the next-generation communication systems. WLAN is offered to operate with the Industrial Scientific and Medical (ISM) operating frequency of 2.4 GHz [2-4]. WLAN is a wireless broadband solution that lot of flexibility in deployment and potential services. WLAN can provide data rate up to 600 Mbps for fixed stations. WLAN is used in modern implementations small in-home networks to large campus-sized networks on airplanes and trains.

FR-4 substrate with dielectric constant of 4.4 and loss tangent of 0.02 is used in the microstrip structure; whereas 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 [5, 6]. So an optimization between bandwidth, efficiency and antenna size had to be done for its fascinating applications. Etching slots are introduced in the patch of the antenna to enhance bandwidth and reduce return loss in the antenna structure [7-9]. Comparatively the gain and directivity of the antenna will be reduced, to equalize the problem DGS has been introduced. A defect had been etched on the ground plane to introduce a DGS. Due to high input impedance of DGS, it is possible to reduce the size of the patch, thereby reducing the size of microstrip patch antenna with increased bandwidth and gain [10]. ADS is the software used for the antenna simulations. It is the world's leading electronic design automation software for Radio Frequency (RF), microwave, and high speed digital application.

For WLAN, WiMAX, Long Term Evolution (LTE), multi-gigabit per second data links, radar and satellite applications, ADS provides full, standards-based design and verification with Wireless Libraries and circuit-system-Electromagnetic (EM) co-simulation in an integrated platform. In bringing out 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, 12]. In this work, a slotted H-shaped microstrip patch antennas with Dumbbell (H) shaped DGS is designed for 2.4 GHz WLAN applications is presented.

This paper is organized as follows, Section I discuss the antenna design for slotted H-shaped MPA for 2.4 GHz WLAN application. Section II brings out simulated results for the antenna parameter such as Gain, Directivity, Return loss, Bandwidth and Efficiency. Section IV concludes the merits of the paper based on the antenna parameter.

II. ANTENNA DESIGN

This section describes the design process of the proposed antenna; a 0.04mm slotted H-shaped patch antenna is designed on a FR4 substrate with thickness of 1.56 mm, a dielectric constant of 4.4 and a loss tangent of 0.02.

A. Slotted H-shaped microstrip patch

The overall view of the slotted H-shaped patch antenna design is shown in Fig. 1. The final optimized geometry was obtained through simulations with the software ADS. The antenna operating at the 2.4 GHz frequency band was achieved using an H-shaped radiator on the substrate with DGS, which is an etching slots in the patch and H (Dumbbell) shaped cut on the ground plane respectively. H-shaped patch on the substrate provides the improved antenna parameters compared to other shaped antenna designs. Further, slots on the surface of the patch will give increased parametric improvements. Thus the reflection loss will be comparatively low and the user can utilize the radiation pattern efficiently

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without any distortion.

The design of the microstrip patch antenna in made through the size of the ground plane used and the etching slots used in the antenna. The defective ground plane will allow the antenna to produce increased surface current and efficiency and the etching slots improves the return loss. This makes the H-shaped antenna to be more efficient compared to other antennas.

The antenna designed for 2.4 GHz WLAN applications can be efficiently utilized because this will reduce the manufacturing cost of the equipment. In the proposed antenna the gain and the directivity is improved compared to existing antennas for WLAN application.

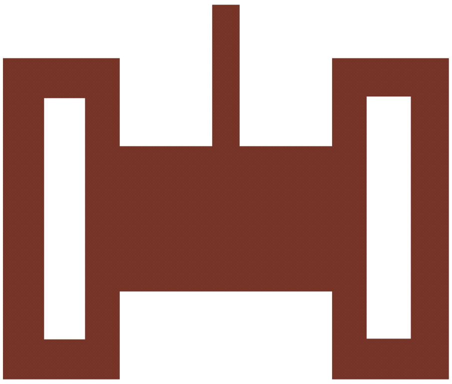

Fig. 1 Design of slotted H-shaped microstrip patch

B. 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. These attributes, along with good fabrication characteristics, lend utility to this grade for a wide variety of electrical and mechanical applications. FR-4 copper-clad sheets are fabricated with circuitry interconnections etched into copper layers to produce printed circuit boards. The operating frequency (f_r) is considered as 2.4 GHz and the height of the dielectric substrate (h) is considered as 1.56 mm for each of the antenna. 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 [13, 14].

Calculation of Patch Width (W):

$$W = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r}} \qquad (1)$$

Where, c = Velocity of light in free space

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

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

Calculation of Patch Length Extension (ΔL):

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

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

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

Calculation of Patch Length (L):

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

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

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

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

C. Defective ground surface in ground plane

The DGS is placed at a dimension of 16.8 mm from the upper and lower sides of the edge and 18.9 mm from the left and right sides of the ground plane. It is placed on the FR4 substrate. The DGS allows the antenna to produce increased directivity, gain and efficiency and the etching slots improve the bandwidth and return loss. As in Table I, a ground plane consisting of 39 x 47 mm^2 metal patches periodical along the x-axis and y-axis is determined. Finally, the dimensions of the

Table I. General specification of the H-shaped MPA

Antenna Parts	**Parameters (symbols)**	**Values in mm**
Substrate	Length (L_s)	39
	Width (W_s)	47
	Height (h)	1.56
Patch	Length (L_p)	30
	Width (W_p)	38
	Thickness (t)	0.04
Feed line	Width (W_f)	2.4
Ground plane	Length (L_g)	39
	Width (W_g)	47
	Thickness (t)	0.04

DGS and the position of the antenna relative to the DGS were shown in Fig. 2 and 3 respectively. Parametric studies are provided in Fig. 4, 5, 6, 7, 8, 9 and 10 are to investigate the effect of the design parameters on the antenna characteristics. By the influence of H, the horizontal and vertical position of the antenna ground plane is investigated in Fig. 2. Finally, the effect of DGS the horizontal position of the antenna relative to the ground plane is investigated in Fig. 3, showing large influence on the axial ratio characteristics at 2.4 GHz.

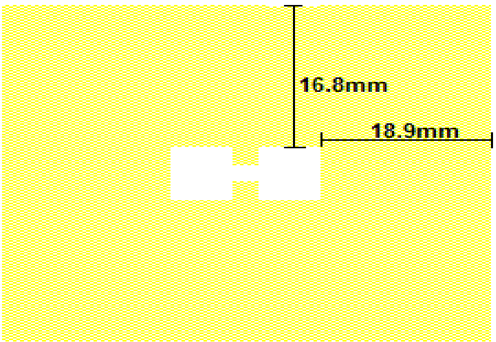

Fig. 2 Positioning of the Dumbbell (H) shaped DGS structure for 2.4 GHz

The Fig. 2 represents the appropriate position where the Dumbbell (H) shaped DGS on the ground plane. The dumbbell shape is been chosen because the antenna structure is symmetrical. The positioning of DGS is at the centre of the ground plane.

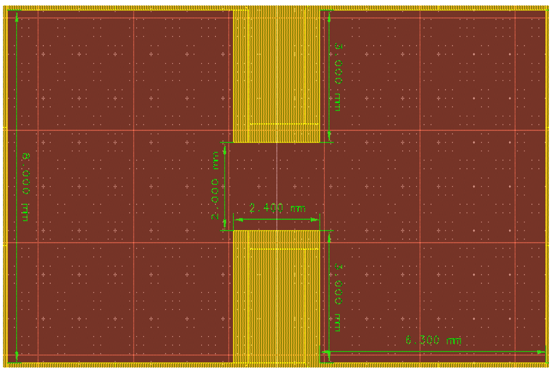

Fig. 3 Dimensions of the 'Dumbbell (H)' shaped defect for 2.4 GHz

The dimension of the Dumbbell (H) shaped is represented in the Fig. 3. This structure is obtained by adjusting the DGS on the ground plane. This DGS improves the bandwidth, gain and directivity of the antenna.

III. SIMULATION RESULTS

The simulated antenna parameters have successfully achieved for 2.4 GHz WLAN applications. The antenna exhibits 2.4 GHz (2.371 - 2.500 GHz) frequency.

A. Return loss

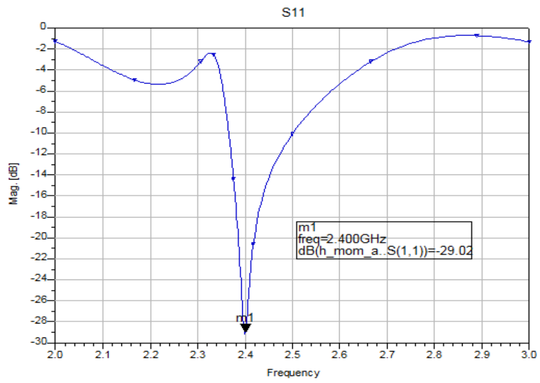

Fig. 4 Return loss

The return loss is to be reduced to obtain a preferable radiated output from an antenna. The Fig. 4 shows the return loss value of the designed antenna is -29.02 dB for the operating frequency of 2.4 GHz. Thus, the slotted H-shaped microstrip patch antenna provides a good return loss value.

B. Smith chart

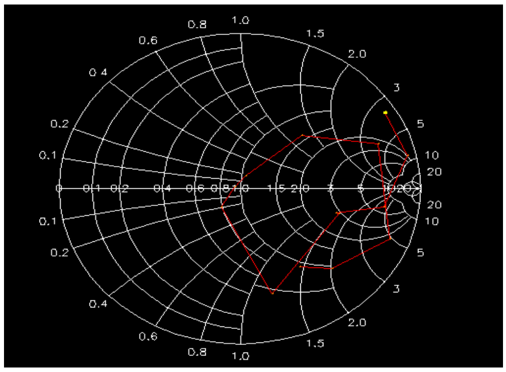

Fig. 5 Smith chart

The smith chart provides the complex reflection coefficient in polar form for arbitrary impedance of the antenna. The Fig. 5 shows the actual reflection coefficient and the impedance matching in the antenna.

C. Impedance matching

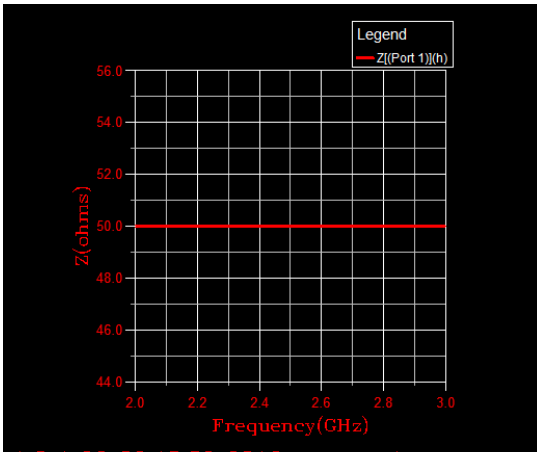

Fig. 6 Impedance

The input impedance of an antenna needs to be close to the amplifier impedance; otherwise the signal is reflected back and not radiated by the antenna. Here, Fig. 6 shows antenna provides an impedance value of 50 ohms which provides a good impedance matching between the transmission line and the antenna.

D. Bandwidth

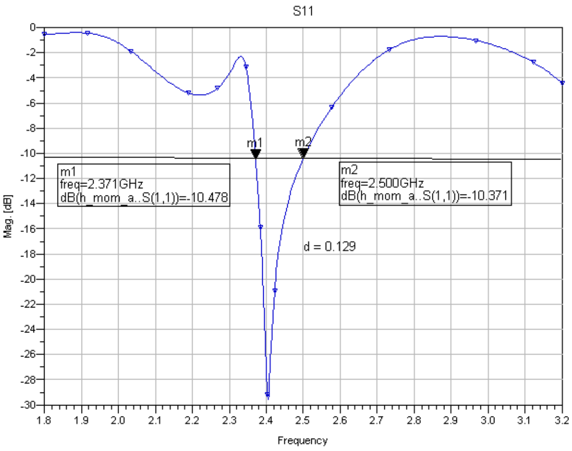

Fig. 7 Bandwidth

The bandwidth is the range of frequencies over which the antenna can operate correctly. The DGS used in the proposed antenna will provide an enhanced bandwidth with a good gain and directivity values. The Fig. 7 shows that the antenna has a wider bandwidth of 129 MHz for which the antenna can operate effectively.

E. Gain and Directivity

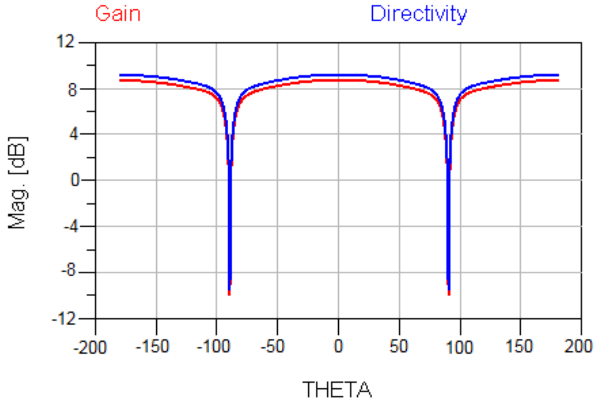

Fig. 8 Gain and Directivity

Directivity is a measure of the power density the antenna radiates in the direction of its strongest emission. The gain is that how well the antenna converts the input power into radio wave. The Fig. 7 represents the gain and the directivity of the antenna is 8.961 dB and 9.674 dB respectively.

F. Efficiency

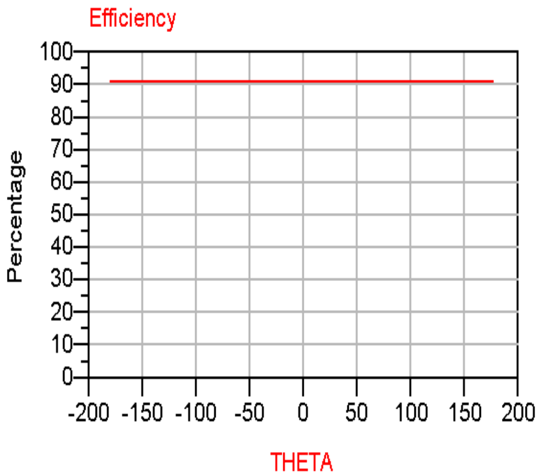

Fig. 9 Efficiency

The efficiency of an antenna is the power delivered to the antenna relative to the power radiated from the antenna. The Fig. 9 represents that the proposed antenna provides a higher efficiency value of 91%.

G. *Radiation pattern*

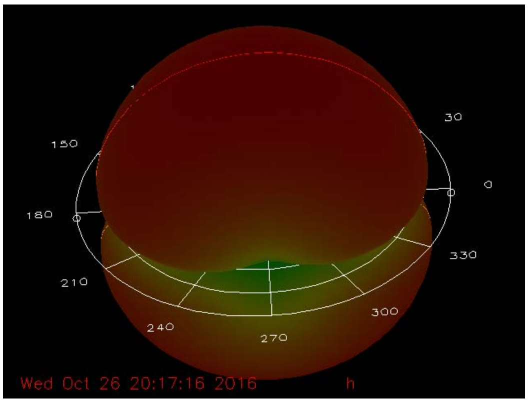

Fig. 10 Radiation pattern

The radiation pattern or antenna pattern or far-field pattern refers to the directional dependence of the strength of the radio waves from the antenna. Thus the Fig. 10 shows the radiation pattern of the proposed antenna.

Table II. Simulated output obtained from slotted H-shaped MPA with dumbbell (H) shaped DGS

Frequency	2.4 GHz
Gain	8.961 dB
Directivity	9.674 dB
Bandwidth	129 MHz
Return loss	-29.02 dB
VSWR	1.107
Efficiency	91%
Impedance matching	50 ohms

The simulated results are obtained by using the ADS software which provides the platform for preparing the H-shaped microstrip patch antenna. The Table II shows the relative antenna parameter values of the proposed antenna design.

IV. CONCLUSION

The Slotted H-shaped MPA with dumbbell (H) shaped DGS is designed for the operating frequency of 2.4 GHz which is used for WLAN applications. The proposed antenna design produces improved antenna parameters such as directivity and gain of 9.674dB and 8.961dB respectively with preferable return loss of -29.02dB and has a good impedance matching (50 ohms). It has a VSWR value of 1.107 and the bandwidth is 129 MHz (2.371 – 2.500 GHz) for 2.4 GHz WLAN frequency. The efficiency of the antenna is 91% which has relatively high gain and wider bandwidth with expected return loss reduction. Thus, this antenna which is used for WLAN applications brings potential benefits in terms of coverage, power consumption, good impedance matching, high efficiency and wider bandwidth.

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