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DESIGN OF SLOTTED H-SHAPED PATCH ANTENNA FOR 5.2 GHz WLAN APPLICATIONS

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ABSTARCT

In this paper, an H-shaped microstrip patch antenna (MPA) with slots and Defected Ground Structure (DGS) is designed. The proposed antenna consists of a slotted H- shaped patch on the Flame Retardant 4 (FR4) substrate with dielectric constant of 4.4 and the ground plane consist of a dumbbell (H) shaped DGS. The antenna is symmetrical and the input is given through microstrip feeding. The overall size of the antenna is 21×26×1.6mm. Its operating frequency is 5.2 GHz used for Wireless local area network (WLAN) applications. Moreover, in comparison with other shapes of MPA the proposed design enhances the bandwidth and decreases the return loss using slots and DGS. It also provides good impedance matching. The simulation parameters are investigated using Advanced Design Software (ADS).

Keywords: H-shaped microstrip patch, Etching slots, DGS, FR-4 substrate, ADS and WLAN application.

I. INTRODUCTION

Microstrip patch antennas have achieved great advancement in recent years. Compared with conventional antennas, microstrip patch antennas have many 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. Microstrip patch antenna systems have become more essential for the next-generation communication systems where several wireless communication application [2-4]. WLAN is a wireless broadband solution that offers a rich set of features with a lot of flexibility in terms of deployment options and potential service offerings [5]. WLAN can provide up to 600 Mbps for fixed stations. In many cases this has resulted in competition in markets which typically only had access through an existing incumbent DSL operator. FR4 is a dielectric substrate used in the design of the proposed antenna. This substrate has a dielectric constant of 4.4 and loss tangent value of 0.02. Thick substrate with lower dielectric constant had been proposed to increase the bandwidth and antenna efficiency, but at the expense of larger element size which arose questions over the portability of the antennas. On the other hand, thin substrate with higher dielectric constant had been proposed to minimize antenna size, but it decreased antenna bandwidth and efficiency [6, 7]. The overall size of the FR4 substrate used in the proposed antenna is 21x26x1.56 mm. 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 improve the reflection coefficient in the antenna structure. It is the cut made in the patch which reduces the surface area of the patch and improves the surface current on the antenna [8, 9]. There are two slots made on the patch of the proposed H-shaped MPA. Thus, the proposed antenna design provides an improved return loss and bandwidth. A defect had been etched or a slot had been cut on the ground plane to introduce a DGS [10]. Due to high input impedance of DGS, it was possible to reduce the size of the patch, thereby reducing the size of microstrip patch antenna with increased bandwidth and gain.

ADS is the world's leading electronic design automation software for RF, microwave, and high speed digital applications. In a powerful and easy-to-use interface, ADS pioneers the most innovative and commercially successful technologies, such as X-parameters and 3D EM simulators, used by leading companies in the wireless communication & networking and aerospace & defense industries. For WLAN, WiMAX, LTE, multi-gigabit per second data links, radar, & satellite applications, ADS provides full, standards-based design and verification with Wireless Libraries and circuit-system-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 paper, a Slotted H-shaped MPA with DGS is presented. The antenna design is organized as follows, Section I discuss the antenna design which consist of patch, substrate and DGS. 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

The design of Microstrip patch antenna consists of three different layers. The upper layer is the patch which is in the shape of alphabet H with slots on it. The middle layer is a FR4 dielectric substrate of 1.56 mm thickness. The last layer is the ground plane which has a Dumbbell (H) shaped DGS in it. The design process of the proposed antenna has a 0.04 mm slotted H-shaped patch 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 and ground plane of 0.04 mm is mounted on the other side of the substrate.

2.1 Slotted H-shaped microstrip patch

The overall view of the slotted H-shaped patch is shown in Fig. 1. The final optimized geometry is obtained through simulations with ADS software. The antenna operates at the 5.2 GHz frequency band. The H-shaped patch 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. Thus the reflection loss will be comparatively low and the user can utilize the radiation pattern efficiently without any distortion. The antenna designed for 5.2 GHz can be used in WLAN applications where the frequency can be efficiently utilized because of less manufacturing cost of the antenna. The design of slotted H-shaped patch is shown in the Fig. 1.

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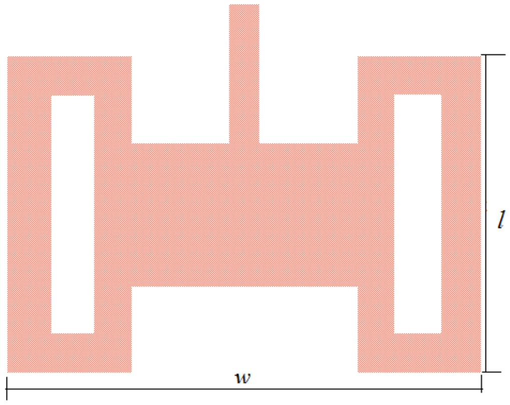

Fig. 1 Design of slotted H-shaped microstrip patch

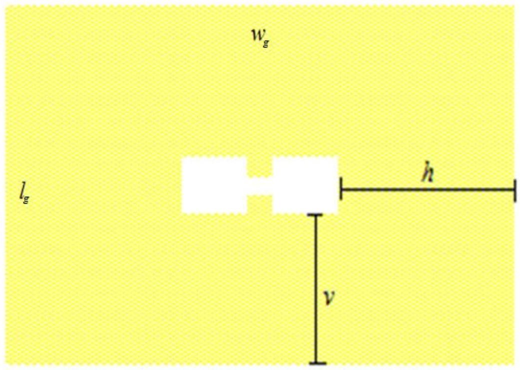

Fig. 2 Position of H-shaped DGS

2.2 FR4 Substrate

FR4 is a dielectric material with relative dielectric constant (ε_r) of 4.4 for the substrate and copper (Cu) is used for the patch, ground plane and microstrip feeding line of the antenna. FR-4 glass epoxy is a versatile high-pressure thermo set plastic laminate grade with good strength to weight ratios. The material is known to retain its high mechanical values and electrical insulating qualities in both dry and humid conditions. 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 [13]. The operating frequency (f_r) is considered as 5.2 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*):

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

Where, *c* = Velocity of light in free space

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

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

Calculation of Patch Length Extension (ΔL):

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

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

$$L_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_{reff}}} \tag{4}$$

Calculation of Patch Length (L):

$$L = L_{eff} - 2\Delta L \tag{5}$$

Calculation of Ground Plane Width (W_g), Ground Plane Length (L_g):

$$W_s = W_g = 6h + W \tag{6}$$

Calculation of Substrate Length (L_s), Substrate width (W_s):

$$L_s = L_g = 6h + L \tag{7}$$

Table I. Dimensions of H-shaped MPA

Antenna Part	**Parameters(symbols)**	**Value in mm**
Substrate	Length (L)	21
	Width (W)	26
	Height (h)	1.56
Patch	Length (L_p)	30
	Width (W_p)	39
	Thickness (t)	0.04
Feed line	Width (W_f)	2.4
Ground plane	Length (L_g)	40
	Width (W_g)	49
	Thickness (t)	0.04

2.3 Defective ground surface in H-shaped patch antenna

The H-shaped patch antenna with DGS was placed at a distance of 5 mm from the vertical side of the edge and 7 mm from the horizontal side of the ground plane is placed on the FR4 substrate for 5.2 GHz. As a result, a ground plane consisting of 21 x 26 mm metal patches periodical along the x-axis and y-axis was determined to give the best results. Finally, the dimensions of the DGS and the position of the antenna relative to the DGS were further optimized to provide the best characteristics at the intended frequency of 5.2 GHz.

It is observed that the reflection coefficients change only slightly, while the antenna characteristics change significantly. The influence of H, the vertical position of the antenna ground plane, is investigated in Fig. 2. Large changes are observed in both the reflection coefficient and the AR characteristics.

From the Fig.1 and Fig. 2, the dimensions of the H-shaped MPA are made clear. The Table I represents the overall dimension of the patch antenna which are calculated using the equations (1) to (7). The antenna is

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designed using ADS software and the outputs are simulated for the respective design. The simulated results are discussed in the next section provides improved antenna parameters because the slotted H-shaped patch provides high efficiency and reduced return loss; microstrip inset feed will provide a good impedance matching and DGS provides a wider bandwidth.

IV. SIMULATED RESULTS

The parameters of the antenna design are obtained through the ADS software. The simulated results provide a good and improved antenna parameters compared to other existing systems. The antenna design has successfully achieved operation for 5.2 GHz WLAN applications. The simulated antenna parameters are explained below.

4.1 Return loss

The return loss of an antenna should preferably less because the power radiated by the antenna will be reflected back due to higher return loss. The value of the return loss of the designed antenna is -31.806 dB for 5.2 GHz operating frequency as shown in Fig. 3.

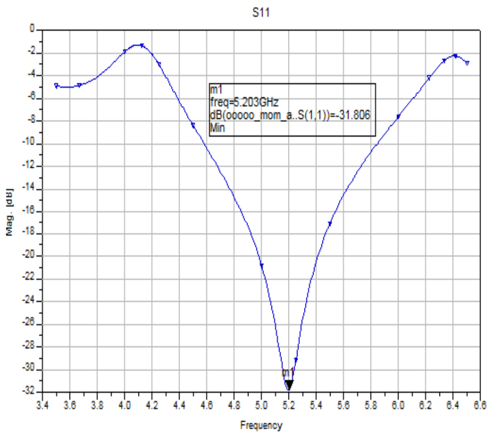

Fig. 3 Return loss

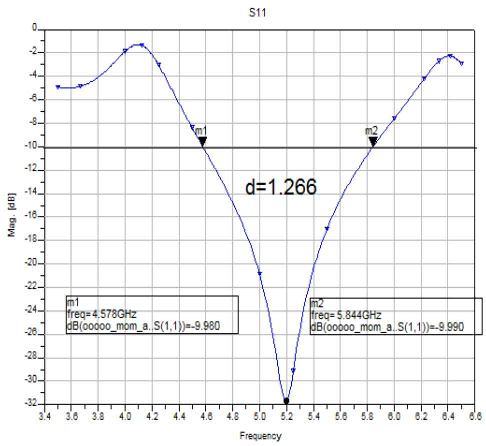

Fig. 4 Bandwidth

4.2 Bandwidth

Bandwith is the range of frequency over which the designed antenna operates. DGS in the antenna design will provide a very wider bandwidth of 1266 MHz ranges from 4.57 GHz to 5.84 GHz. A return loss of -10 dB is enough for the antenna to operate efficiecntly. So the antenna bandwidth is measured at -10 dB value of S11as shown in Fig. 4.

4.3 Gain and Directivity

The gain of the antenna is how efficiently the antenna converts the electrical signal into radio waves. The directivity is the measure of power density that a antenna radiates in a particular direction. The designed antenna provides a preferable gain and directivity values of 5.564 dB and 5.621 dB respectively as shown in Fig.5.

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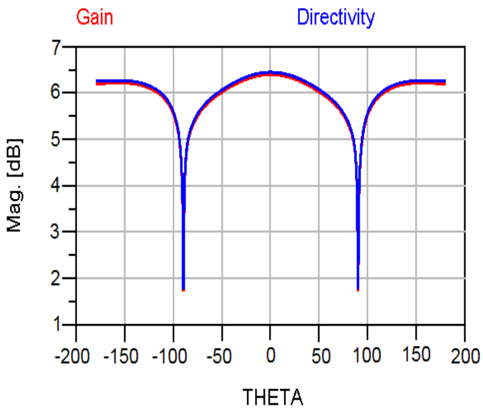

Fig. 5 Gain and Directivity

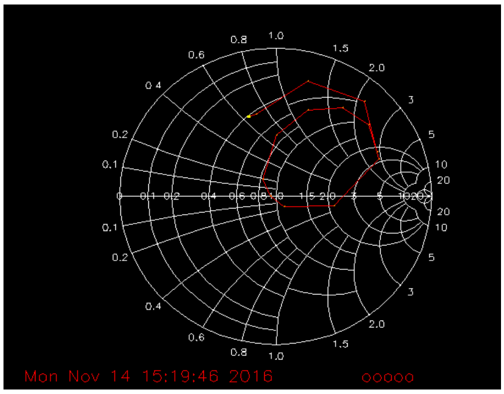

Fig. 6 Reflection coefficient

4.4 Reflection coefficient

The smith chart shows the reflection coefficient in the polar form for 5.2 GHz operation frequency. The Fig. 6 shows the reflection coefficient obtained for the designed antenna.

4.5 Radiation pattern

Radiation pattern refers to the directional dependence of the strength of the radio waves from the antenna. The radiation pattern of the designed antenna for 5.2 GHz is shown in Fig. 7.

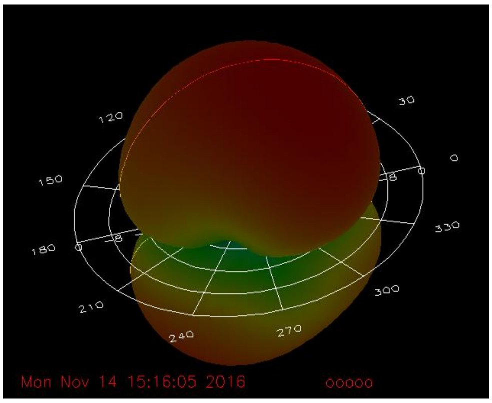

Fig. 7 Radiation pattern

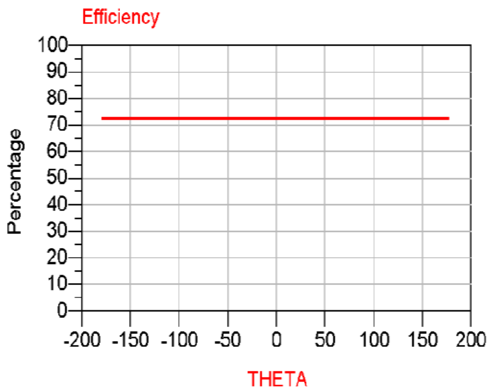

Fig. 8 Efficiency

4.6 Efficiency

The efficiency of an antenna is the power delivered to the antenna relative to the power radiated from the antenna. The Fig. 8 represents that the proposed antenna provides a higher efficiency value of 72%.

4.7 Impedance matching

The impedance matching between the antenna and the transmission line should be close to each other. Otherwise, the radiated signal will be reflected back or will not be radiated. As shown in Fig. 9, the impedance value of the designed antenna is 50 ohms. Thus, the antenna provides a good impedance matching.

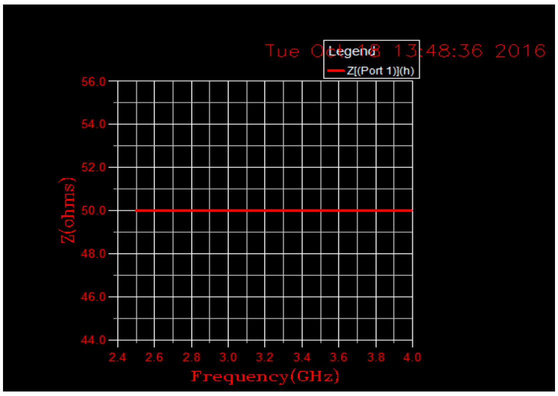

Fig. 9 Impedance

Table II. Output for Slotted H-Shaped MPA with DGS

Frequency	5.2 GHz
Gain	5.564 dB
Directivity	5.621 dB
Bandwidth	1266 MHz
Return loss	-31.80 dB
Efficiency	72%
Impedance matching	50 ohms

The Table II represents the simulated data output obtained from the slotted H-shaped MPA with Dumbbell (H) shaped DGS. The simulated results of the proposed antenna provides an improved directivity and gain, reduces return loss and wider bandwidth with a good impedance matching.

V. CONCLUSION

In this paper, the H-shaped microstrip patch antenna with dumbbell shaped DGS is proposed 5.2 GHz frequency. The proposed antennas design provides improved antenna parameters such as preferable return loss value with a good impedance matching, improved gain and directivity and wider bandwidth with higher efficiency. So, this paper concludes that the slotted H-shaped antenna with DGS will exhibits improved antenna parameters for the 5.2 GHz WLAN application and brings potential benefits in terms of coverage, power consumption, good impedance matching, wider bandwidth and efficiency.

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