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Survey on slotted H-shaped MPA design for different ISM band radio frequencies

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Abstract

Objectives: To improve the parameters of the microstrip patch antenna (MPA) by introducing slotted H-shaped patch with Dumbbell (H) shaped Defective Ground Surface (DGS).
Methods/Statistical analysis: MPA is playing a vital role in various wireless applications such as Wireless local area network (WLAN) and Worldwide Interoperability for Microwave Access (WiMAX) which are widely used in mobile devices such as pocket computers, dongles and intelligent phones. However there are some performance degradations in the antenna parameters. Hence in this paper, this problem in the patch antenna will be minimized.
Findings: The designed antenna structure has a slotted H-shaped microstrip patch with dumbbell (H) shaped DGS on the ground plane. Through this type of antenna design for all different ISM frequencies are standardized with the slotted H-shaped MPA compared to other shapes. Thus, this slotted H-shaped antenna is preferable compared the usage of other shaped antenna in various part of the application.
Improvements/Applications: This slotted H-shaped microstrip patch offers improved antenna parameters compared to other shaped patch antenna. It can be used for 2.4/5.2/5.8 GHz WLAN and 3.5 GHz WiMAX applications is proposed.

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

1. Introduction

Microstrip patch antennas have a metallic patch and ground with a dielectric medium (substrate) in between. Compared with conventional antennas, microstrip patch antennas have many advantages such as low profile, compactness, easy fabrication, easy installation, low cost etc. But these antennas have major disadvantages like low efficiency, poor polarization purity [1]. MPA systems have become more essential for the next-generation communication system has various wireless communication applications such as WLAN: 2.35-2.45, 5.15-5.25, 5.15-5.25 and 5.75-5.85 GHz and WiMAX: 3.45-3.55 GHz. Several countries around the world such as United States, Canada, Italy, Poland, Spain and Australia have already used both WLAN and WiMAX technologies to provide wireless high-speed Internet and network connections [2]. Etching slots are introduced in the antenna to improve the reflection coefficient in the antenna structure [3-5].

FR-4 glass epoxy is a versatile high-pressure thermo set plastic laminate grade with good strength to weight ratios. Thick substrate in the patch antenna 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 [6, 7]. So an optimization between bandwidth, efficiency and antenna size had to be done for its fascinating applications.

A defect has been etched on the ground plane to introduce a DGS [8]. Due to high input impedance of DGS, it was possible to reduce the patch size; thus the microstrip patch antenna will provides an increased bandwidth and gain [9]. 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 [10]. The etching slots in the patch are used to reduce the return loss and improve bandwidth. In this work, a quad-band microstrip patch antennas for 2.4/5.2/5.8 GHz WLAN and 3.5 GHz WiMAX applications is presented.

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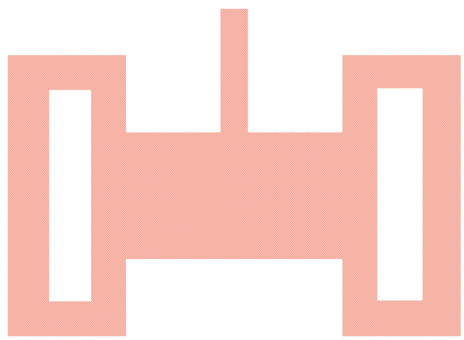
Antenna design

This section provides the design structures of the proposed antenna which consists of slotted microstrip patch, FR-4 substrate and dumbbell (H) shaped DGS; the slotted H-shaped patch antenna is designed on a FR4 substrate and the ground plane has a dumbbell shaped defective ground structure.

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). Four operating frequency bands at the 2.4/3.5/5.2/5.8 GHz are achieved using an H- shaped radiator with a Dumbbell (H) shaped DGS and the etching slots in the patch. The defective ground plane will make the antenna to produce increased surface current and efficiency and the etching slots improves the return loss. This makes the slotted H-shaped antenna to be more efficient compared to other shaped antennas [1]. Thus the reflection loss will be comparatively low and the user can utilize the radiation pattern efficiently without any distortion. Thus, there will not be any difficulty in providing different shapes of antenna for each frequency. In the proposed antenna parameters are improved compared to shaped existing antennas.

Figure 1. Design of H-shaped MPA



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 MPA's widely uses the FR-4 substrate because it provides more efficiency compared to other substrate, it has medium dielectric constant and its availability is easier. The operating frequency *(f_r)* is considered as 2.4/3.5/5.2/5.8 GHz and the height of the dielectric substrate (*h*) is 1.56 mm, Patch width (*W*), patch length extension (*ΔL*), effective dielectric constant (ε_{reff}), patch length (*L*), effective patch length (L_{eff}), ground plane width (W_g), ground plane length (L_g), substrate length (L_s) and substrate width (W_s) of the antennas are calculated for of *(f_r)* and (ε_r)as in [11, 12].

Calculation of Patch Width (*W*):

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

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):*

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

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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), Substrate Length(L_s), Substrate width (W_s)

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

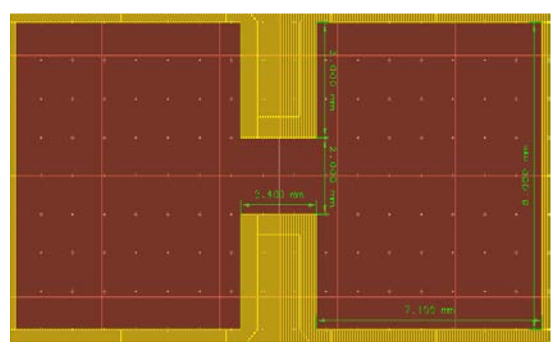
$$L_s = L_g = 6h + L \tag{7}$$

Dumbbell (H) shaped defective ground surface

The slotted H-shaped patch antenna with DGS was placed at a distance of 16.8 mm from the vertical and 18.9 mm from the horizontal side of the ground plane. By adjusting the size of the DGS on the FR4 substrate the operating frequency is varied according to the increasing in GHz with reduction in DGS size, this makes the antenna to propagate in four different operating frequencies. Then the antenna characteristics for different number of unit cells were studied. As a result, a ground plane consisting of 30 x 39 mm, 26 x 35 mm, 18 x 27 mm, 30 x 39 mm and 16 x 25 mm metal patches for 2.4/3.5/5.2/5.8 GHz frequencies along the x-axis and y-axis was determined to give the best results. Finally, the dimensions and the position of the antenna to the DGS were further optimized to provide the characteristics at the intended frequencies of 2.4/3.5/5.2/5.8 GHz. The total size of the substrate is 40 x 49 x 1.56 mm, ground plane is 40 x 49 x 0.04 mm and the patch is 30 x 39 x 0.04 mm for 2.4 GHz frequency. Parametric results are provided to investigate the design parameters on the antenna characteristics. The Figure2 shows the size of the metal patch, on the four bands. As area is increased, both upper bands tend to shift to the lower frequency region. Increasing or decreasing H-shaped slots causes change in different bands to unintended frequencies and reduction of both the impedance and the bandwidth. Finally, the effect of DGS the horizontal position of the antenna to the ground plane is shown in Figure 3. It shows large influence on the AR characteristics at WLAN frequencies 2.4/5.2/5.8 GHz and WiMAX frequency 3.5 GHz.

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

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



Simulation parameters

Input Impedance

The impedance should be same between the antenna and the transmission cable for an efficient transfer of energy. Transceivers and their transmission lines are designed for 50Ω impedance.

Return loss

The return loss is a logarithmic ratio of the power reflected by the antenna to the power that is fed to the antenna from the transmission line measured in dB.

$$\text{Return loss (in dB)} = 20\log_{10}\frac{\text{SWR}}{\text{SWR}-1}$$

Bandwidth

Bandwidth is the range of frequencies over which the antenna radiates properly. The antenna's bandwidth will exhibit an SWR less than 2:1.

$$\text{Bandwidth} = 100 \times \left(\frac{F_H - F_L}{F_C}\right)$$

Directivity and Gain

Directivity is the ability to focus energy in a particular direction. In a static situation, it is possible to use the antenna directivity to concentrate the radiation beam in the wanted direction and in a dynamic system where the transceiver is not fixed, the antenna should radiate equally in all directions.

$$D = \max_{\theta,\phi} D(\theta,\phi)$$

$$D(\theta,\phi) = \frac{U(\theta,\phi)}{P_{tot}/(4\pi)}$$

$$P_{tot} = \int_{\phi=0}^{\phi=2\pi}\int_{\theta=0}^{\theta=\pi} U sin\theta \, d\theta d\phi$$

Here $\theta and \phi$ - Standard spherical coordinate angles
$U(\theta,\phi)$ - Radiation intensity
P_{tot} - Total radiated power

The gain is the amount of energy radiated in a given direction to the energy an isotropic antenna would radiate in the same direction.

$$G = E_{antenna}.D$$

Here G - Gain of the antenna
$E_{antenna}$-Efficiency of the antenna

Antenna efficiency

The efficiency of an antenna is a ratio of the power delivered to the antenna relative to the power radiated from the antenna.

$$E_{antenna} = \frac{P_{radiated}}{P_{input}}$$

Here $P_{raditated}$-Radiated power
P_{input} - Radiated input power

Table 1. General specification of the h-shaped microstrip patch antenna

Antenna Parts	Parameters (symbols)	Values for 2.4 GHz (mm)	Values for 3.5 GHz (mm)	Values for 5.2 GHz (mm)	Values for 5.8 GHz (mm)
Substrate	Length (L_s)	40	34	26	24
	Width (W_s)	49	45	37	35
	Height (h)	1.56	1.56	1.56	1.56
Patch	Length (L_p)	30	26	18	16
	Width (W_p)	39	35	27	25
	Thickness (t)	0.04	0.04	0.04	0.04
Feed line	Width (W_f)	2.4	2.4	2.4	2.4
Ground plane	Length (L_g)	40	26	18	16
	Width (W_g)	49	35	27	25
	Thickness (t)	0.04	0.04	0.04	0.04

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3. Conclusion

The slotted H-shaped antenna with DGS will exhibit improved antenna parameters for the 2.4/5.2/5.8 GHz WLAN and 3.5 GHz WiMAX applications.

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