DESIGN OF A DUAL-POLARIZED MICROSTRIP PATCH ANTENNA WITH V-SHAPED SLOT FOR 2.4 GHz WLAN APPLICATIONS

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ABSTRACT

This paper presents the design of a dual-polarized microstrip patch antenna used for 2.4 GHz WLAN applications. The designed antenna consists of a circular patch fabricated on low-cost FR-4 substrate with a V-shaped slot carved on its surface and a circular metal reflector. The antenna size and positions of the two feeding ports using coaxial cables are optimized to obtain a dual-polarized antenna having resonant frequency at 2.44 GHz, about 8-dBi peak gain, and the isolation between the two ports below −15 dB in the required band. The measured S-parameter results show good agreement with the simulation. The proposed antenna can be used for 2.4 GHz wireless access points (APs) with 2×2 multiple-input multiple-output (MIMO) antenna systems.

Keywords: microstrip antennas, dual polarization, WLAN, MIMO.

1. INTRODUCTION

The rapid growth in broadband wireless communications systems has increased the demands to enhance communications capacity and quality. One of the most widely used techniques is polarization diversity, in which the antenna of the system should have dual polarization [1 - 6]. For antenna engineering, designing dual-polarized antennas having high isolations between ports has been a topic of great interest and several techniques for improving isolations have been reported in recent years [7, 8].

This paper presents a new design of a dual-polarized radiation for a circular microstrip patch antenna excited by two coax-line feeds. The antenna is designed for 2.4 GHz WLAN applications. By introducing a V-shaped slot cut on surface of the FR-4 patch, simulation results have shown that the isolations between the two ports of the antenna can be improved by 6 dB in the required band compared to the conventional one. The measured S-parameters results show good agreement with the simulation.

2. ANTENNA STRUCTURE AND DESIGN

Figure 1 shows the configuration of the proposed dual-polarized microstrip patch antenna. The circular patch has a radius of a and is printed on low-cost FR-4 substrate of thickness h_1 = 1.6 mm and relative permittivity ε_1 = 4.6. A V-shaped slot is cut out on the surface of the substrate. The patch is stacked above the metal reflector by a distance h_2. The two coaxial-probe feedings are located at distances of r_0 from the center of the circular patch and situated perpendicular to each other.

Approximate design techniques are first used to obtain initial parameters of the microstrip patch antenna. The effective radius of the circular patch is found by [9, 10]

$$a_e = a\left\{1+\frac{2h}{\pi a\varepsilon_r}\left[\ln\left(\frac{\pi a}{2h}\right)+1.7726\right]\right\}^{0.5} \tag{1}$$

where: a = physical radius of circular patch; h = thickness of the substrate; ε_r = dielectric constant of substrate.

and

$$a_e = \frac{1.8412}{2\pi f_r\sqrt{\varepsilon_r}}c \tag{2}$$

where f_r = resonant frequency. In this case, f_r = 2.44 GHz; c = speed of light.

The physical radius of the circular patch is calculated by

$$a = \frac{F}{\left\{1+\left(\frac{2h}{\pi\varepsilon_r F}\right)\left[\ln\left(\frac{\pi F}{2h}\right)+1.7726\right]\right\}^{0.5}} \tag{3}$$

where

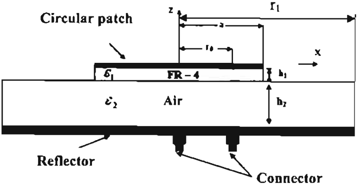
$$F = \frac{8.791\times10^9}{f_r\sqrt{\varepsilon_r}} \tag{4}$$

Some other parameters of the antenna are determined as follows:

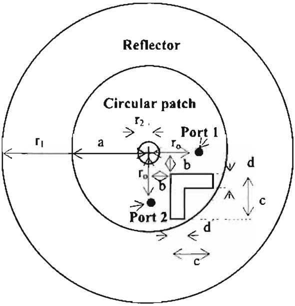
$$\lambda = \frac{c}{f_r\sqrt{\varepsilon_r}} \approx 57mm \tag{5}$$

Spacing between reflector and circular patch is $\lambda/10$; Diameter of the reflector is 2λ; Feeding port position r_0 is $\lambda/4$.

The diameter of the circular patch, permittivity of the substrates, the spacing between reflector and circular patch, and location of the feeding ports are important parameters in the design of microstrip antennas. To further improve isolation between the two ports of the antenna, a V-shaped slot is cut on the FR-4 patch's surface. The values of the designed antenna's dimensions are obtained through optimization to achieve the best performance in terms of S-parameters, gain, and radiation pattern. The proposed antenna is simulated by using Ansys High Frequency Structure Simulator (HFSS) [11]. The ultimate values of the parameters of the proposed antenna are listed in Table 1.



(a)



(b)

Figure 1. Geometry and dimensions of the proposed antenna: (a) side view and (b) top view.

Table 1 Detailed dimensions of the proposed antenna.

Parameter	r_0	r_1	r_2	h_2
Value (mm)	13	55	3	6
Parameter	*a*	*b*	*c*	*d*
Value (mm)	28.6	10	13	4

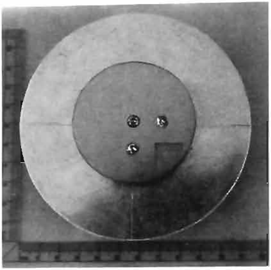


Figure 2 Top view of the antenna prototype.

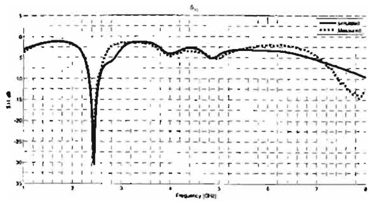
3. EXPERIMENTAL RESULTS

To validate the design, the S-parameters of the proposed antenna are simulated by using Ansys HFSS. The antenna has also been fabricated and measured. The top view of the antenna prototype are shown in Fig. 2.

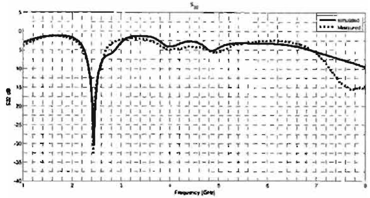
Figure 3 shows the measured S-parameters of the proposed antenna (dash lines) compared to the simulated ones (solid lines). As shown in Fig. 3, throughout the WLAN frequency band (2.4 ~ 2.484 GHz), the values of return loss for port 1 and port 2 are better than – 10 dB. The isolation between two ports in the required band is lower than – 15 dB. Besides, one can observe that the bandwidths of – 10 dB reflection coefficient are about 200 MHz. The measurement was taken by using the Rohde & Schwarz ZBV8 vector network analyzer.

In this work, the gain-transfer method was applied to determine the designed antenna gain. In this experiment, an Agilent E4421B analog RF signal generator was used as the transmitter, and an Agilent E7405A spectrum analyzer was employed to measure the received signal power. A 2-dBi omnidirectional antenna was used as the reference antenna. Measurements were performed at 2.45 GHz, the center frequency of the 2.4-GHz WLAN band. Figure 4 presents receiving RF power levels for the two cases: the omnidirectional antenna was used as the transmitting antenna (Fig. 4a), and the proposed antenna was used as the transmitting antenna (Fig. 4b). From the measured results, it can be seen that the gain of the designed antenna is 5.63 dB higher than that of the omnidirectional one. It means that the proposed antenna has a peak gain of 7.63 dBi.

The calculated far-field 2-D and 3-D radiation patterns of the antenna at 2.44 GHz are plotted in Fig. 5. It can be seen that the half-power beam width is about 60 degrees in the E-plane. The calculated peak gain of the antenna is 8.43 dBi at the center of the 2.4 GHz WLAN band. The simulated isolation S_{21} (S_{12}) results are depicted in Fig. 6, where the antenna with the V-shaped slot provides about 6-dB isolation improvement in the 2.4 GHz band compared to the one without the V-shaped slot. The simulated axial ratio of the antenna is illustrated in Fig. 7. It can be seen that the axial ratio remains below 4 dB in the 2.4–2.5 GHz frequency band.



(a)



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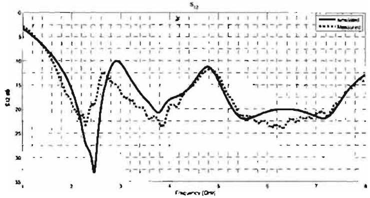
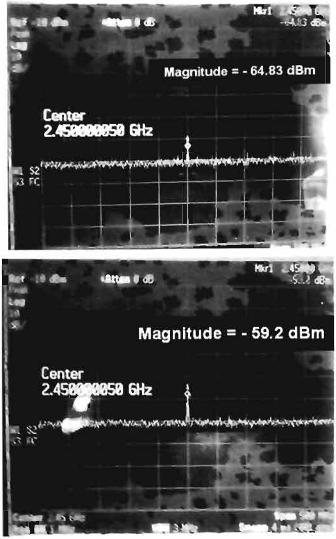


(c)

Figure 3. Measured and simulated S-parameters of the proposed antenna: (a) return loss S_{11} of port 1; (b) return loss S_{22} of port 2 and (c) isolation S_{12} (S_{21}).

Furthermore, a commercial IEEE 802.11n wireless LAN access point (AP) having the MIMO 2×2 antenna system (two 2-dBi omnidirectional antennas) was used to verify the antenna performance in practical applications. The designed antenna was connected to antenna connectors of the AP serving as the transmitter, and a laptop computer with built-in antennas was employed as the receiver. The NetStumbler software [12] installed on the computer was used to measure the WLAN signal strength transmitted from the AP. As shown in Fig. 8, the average signal power received when using the proposed antenna is about –57 dBm, compared to that of using the



b)

Figure 4. RF power level received by (a) using a 2-dBi omnidirectional antenna; and (b) using the proposed antenna with one port terminated at 50 Ohms.

standard 2-dBi omnidirectional antennas, about –63 dBm. The test was performed under non-line-of-sight conditions. The measured results show that the proposed antenna improves WLAN signal reception by 6 dB compared to that of the omnidirectional ones.

In order to validate the antenna performance in fading environment, a site survey was performed in the four-floor main building of College of Engineering. Figure 9 shows the floor plan of the 4th Floor in which the AP is placed at a corner of the floor and three test points are located at the other three corners. For this experiment, the designed antenna was directed toward the Test point 1 on the 4th Floor. Measurement was also carried out at the corresponding test points of the first, second, and third Floor. The measured results taken at the three test points of each floor are shown in table 2. It can be seen from Table 2 that the proposed antenna mostly gives higher WLAN signal strengths at Test points compared to that of the original omnidirectional antennas of the AP.

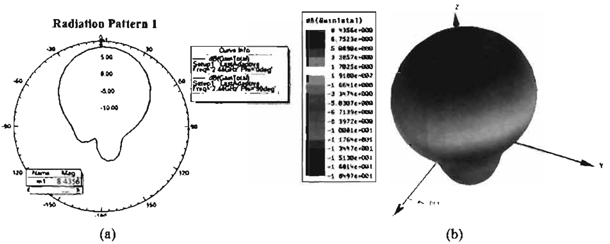


Figure 5. Simulated (a) 2-D and (b) 3-D radiation patterns of the proposed antenna at 2.44 GHz.

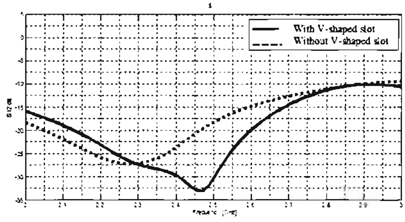


Figure 6. Simulated isolation between the two ports with (solid line) and without (dash line) V-shaped slots.

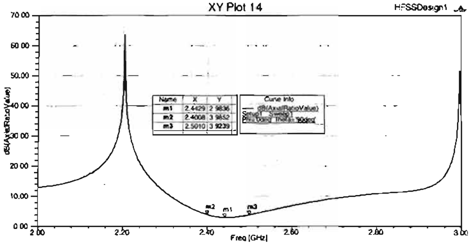


Figure 7. Simulated axial ratio versus frequency.

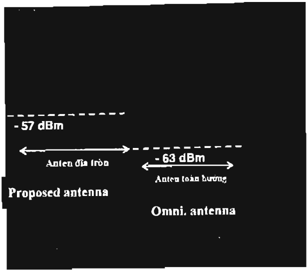


Figure 8. Compared antenna gains under non-line-of-sight conditions.

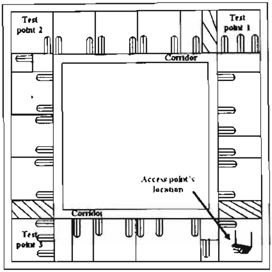


Figure 9. Locations of test points and access point in the 4th Floor.

Table 2. Proposed antenna vs. omnidirectional antennas.

	The proposed antenna			
	1st Floor	*2nd Floor*	*3rd Floor*	*4th Floor*
Test point 1 (dBm)	-70	-70	-66	-54
Test point 2 (dBm)	-78	-73	-75	-68
Test point 3 (dBm)	-78	-76	-73	-73
	Omnidirectional antennas			
	1st Floor	*2nd Floor*	*3rd Floor*	*4th Floor*
Test point 1 (dBm)	-75	-80	-69	-68
Test point 2 (dBm)	-82	-76	-72	-69
Test point 3 (dBm)	-80	-78	-70	-66

4. CONCLUSIONS

A dual-polarized microstrip patch antenna has been proposed and tested. By introducing a V-shaped slot carved on the patch's surface, the isolation between the two ports of the antenna can be improved by 6 dB in the 2.4 GHz band. Measured return loss of the designed antenna is lower than – 10 dB. The isolation between two ports is lower than – 15 dB in the required band. Measured results have verified that a peak antenna gain of about 8 dBi has been obtained. The proposed antenna is expected to be suitable for 2.4 GHz WLAN access points with 2x2 MIMO antenna systems.

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TÓM TẮT

THIẾT KẾ ANTEN VI DẢI PHÂN CỰC KÉP VỚI KHE CHỮ V CHO ỨNG DỤNG WLAN DẢI TẦN 2.4 GHz

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Nội dung bài viết này trình bày về một anten vi dải phân cực kép cho ứng dụng WLAN dải tần 2,4 GHz. Anten được thiết kế bao gồm một tấm mạch in FR-4 hình tròn với một khe được khắc hình chữ V và một tấm kim loại hình tròn (tấm phản xạ). Bản mạch in FR-4 được đặt cách tấm phản xạ một khoảng cách nhỏ. Kích thước của anten và vị trí đặt 2 ngõ vào (port) tiếp tín hiệu sử dụng cáp đồng trục được tối ưu để có được sóng phân kép, tần số cộng hưởng 2,44 GHz, độ lợi đỉnh 8-dBi, và độ cách li giữa 2 ngõ vào dưới – 15 dB. Kết quả đo đạc các thông số S (tổn hao phản xạ) phù hợp với kết quả mô phỏng. Anten cũng có thể được sử dụng như một anten phân cực kép cho các access point (AP) dải tần 2,4 GHz với hệ thống anten MIMO 2×2.

Từ khóa: anten vi dải, phân cực kép, mạng không dây (WLAN), đa ngõ vào và đa ngõ ra (MIMO).