A Single Feed Dual-band (2.4GHz/5.8GHz) Miniaturized Patch Antenna for Wireless Local Area Network (WLAN) Communications

Fanji Meng and Satish K. Sharma

Department of Electrical and Computer Engineering
San Diego State University
5500 Campanile Drive, San Diego, California, USA, 92182-1309

Emails: fjmeng@uestc.edu.cn and ssharma@mail.sdsu.edu

Abstract

In this paper, a single layer, single feed, dual-frequency microstrip patch antenna is proposed. This antenna was design for IEEE 802.11b (2.4GHz~2.4835GHZ) and IEEE 802.11a (5.725GHz~5.825GHz) frequency bands. Its dual-band behavior is achieved by a shorting pin at 2.4GHz and 5.8GHz. In addition, the antenna is miniaturized by 31.8% compared to the conventional rectangular patch without a slot. This antenna has a broadside and symmetrical radiation pattern suitable for wire local area network (WLAN) applications.

1. Introduction

Microstrip antennas are popular because of their small size, low profile, light weight, flexibility, and their compatibility with the integrated circuits [1]. Multiband microstrip antennas are in demand for many applications such as wireless local area network (WLAN) and satellite communications [2], [3]. An ideal two-frequency antenna should have a similar performance in both operating bands in terms of radiation performance and impedance matching. Dual-frequency microstrip antennas could be realized by reactive-loading techniques [4]. It uses a single radiating element with reactive loading for dual resonance. In this paper, a single feed dual-frequency microstrip patch antenna is designed for IEEE 802.11b (2.4GHz~2.4835GHZ) and IEEE 802.11a (5.725GHz~5.825GHz) frequency bands [5]. A reactive loading and shape deformation are used simultaneously to achieve dual-frequency operation. Initially, by shape deformation, two distinct patches are designed to resonate at each of the frequency bands [6]. Then using a shorting pin, the spurious harmonics between these two resonant frequencies are eliminated partly, and a relative pure impedance match is obtained. This antenna is supposed to be used in conjunction with a novel frequency selective surface (FSS) for achieving high gain response. However, for the sake of brevity, these results are not included here and will be presented during the symposium including experimental results.

2. Proposed Antenna Geometry

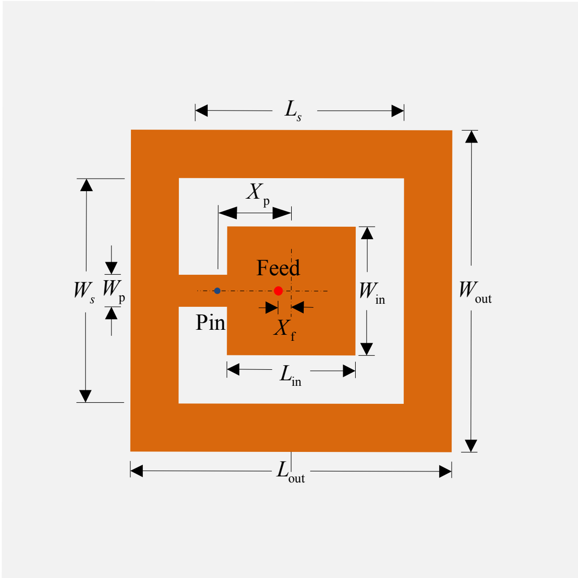
The proposed dual band microstrip patch antenna geometry is shown in Fig. 1. A combination of a rectangular notched, and a rectangular patch are used to achieve two distinct resonant frequencies separated by 2.46:1. The rectangular notched rectangular patch is designed to resonate at 2.4GHz, and the inner rectangular patch is designed to resonate at 5.8GHz. The design procedure consists of three steps. First, two separate antenna elements at the desired frequency bands are designed. Secondly, they are connected by bridge and a shorting pin was set in bridge to separate spurious harmonics. Finally, patch's dimensions and position of feed was optimized to obtain impedance matching in two resonate frequencies.

The dominant mode resonance frequency of the rectangular notched rectangular patch is computed from [6]:

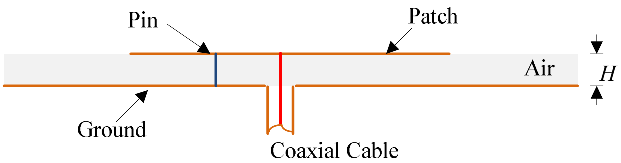
$$f_{01} = \frac{1}{2L_{\text{eff}}\sqrt{\varepsilon_{\text{eff}}\mu_0}} \tag{1}$$

In Equation (1), L_{eff} and ε_{eff} are effective length of resonating patch and effective relative permittivity of substrate, respectively. In order to obtain wider bandwidth, air was selected as this antenna's substrate. Its height H is 3.6mm. According to Equation (1), the rectangular notched rectangular patch with $L_{\text{out}} = 38\text{mm}$ and $W_{\text{out}} = 46.3\text{mm}$ is designed to resonate at 2.4GHz. Taking the rectangular notch effect into consideration, the dimensions are further reduced [7], leading to $L_{\text{out}} = 51.1\text{mm}$, $W_{\text{out}} = 48.6\text{mm}$, $W_s = 35.5\text{mm}$, $L_s = 32.6\text{mm}$. Similarly, according to this

Equation (1), the inner rectangular patch with $L_{in} = 26.3\text{mm}$ and $W_{in} = 23.5\text{mm}$ is designed to resonate at 5.8GHz using the dominant mode resonance frequency. The inner rectangular patch and the outer rectangular loop are linked by an interconnecting bridge with width $W_d = 5.2\text{mm}$.



(a) Top view



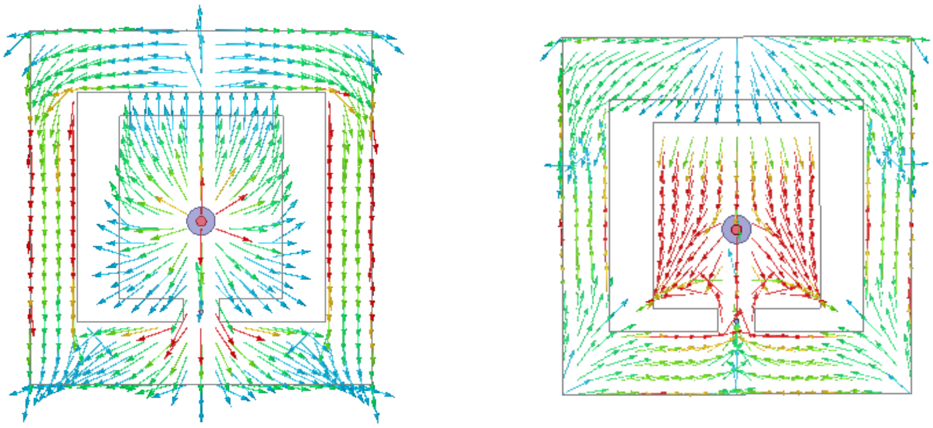
(b) Side view

Fig.1: The proposed dual band antenna separated by 2.46:1 frequency ratio and its design parameters.

Since a feed placement at the outer loop patch increases spurious resonances and adds harmonics that interfere with the upper resonance band, the feed should be placed inside the inner rectangular patch [6]. In addition, a perfect impedance match at the both frequency bands is obtained by an inner patch feed. Thus, for input impedance of 50 ohm, coaxial cable feed position $X_f = 2\text{mm}$. As shown in Fig.1, a shorting pin with radius $R_{pin} = 0.3\text{mm}$ is inserted in the bridge between the two patches with position $X_p = 15\text{mm}$. Combination of the bridge and the shorting via works as a harmonic suppressor that short-circuits the spurious resonance currents and improves the impedance match. The proposed antenna without the pin will have spurious resonances in between the two desired frequency bands, whereas they are all suppressed in this design by employing the shorting pin and a very good impedance match can be obtained. Thus, the shorting pin isolates low and high frequency bands from each other.

3. Simulations Results

The simulated current distribution on patch is shown in Fig. 2. Fig. 2(a) is current distribution on patch when this patch is resonating at 2.4GHz. Similarly, Fig. 2(b) is the current distribution on patch when this patch is resonating at 5.8GHz. From Fig. 2(a) we can find that, when the patch operates in 2.4GHz band, the magnitude of current is higher than the magnitude of current on inner patch. Obviously, under this circumstance, the outer rectangular loop is dominated by radiating element. The current from probe can flow past the connection bridge between inner patch and outer rectangular loop. Similarly, when the patch operates in 5.8GHz band, the magnitude of current on outer rectangular loop is very weak compared to the magnitude of current on inner patch. This is because the shorting pin placed on connecting bridge can short-circuit outward flowing current.   Further, the inner rectangular patch is the dominating radiating element. It is worth pointing that, in this antenna design, the shorting pin placed in the connection bridge couldn't isolate the interference between low frequency and high frequency completely. This can be explained from two aspects: (i) the interval between high and low frequency is not adequately big, and (ii) the length of the connecting bridge is not of adequate long. With the high and low frequency ratio of 2.46:1, even though the length of connecting bridge is very long, we can still obtain good impedance matching. The shorting pin isolates outward flowing current passing on the connecting bridge.



(a) 2.4GHz (b) 5.8GHz

Fig. 2: Vector current distribution of the proposed patch antenna (as shown in Fig. 1)

The simulated reflection coefficient magnitude (S_{11}) of the proposed antenna is shown in Fig. 3. It can be seen that, this antenna has two operating bands around the center frequencies of 2.4GHz and 5.8GHz. In low band, -10 dB bandwidth is between 2.398-2.846GHz, which satisfies IEEE 802.11b (2.4GHz~2.4835GHz) wireless communication band. Similarly, in high band, -10dB bandwidth is between 5.701-5.84GHz, which satisfies IEEE 802.11a (5.725GHz~5.825GHz) wireless communication band applications.

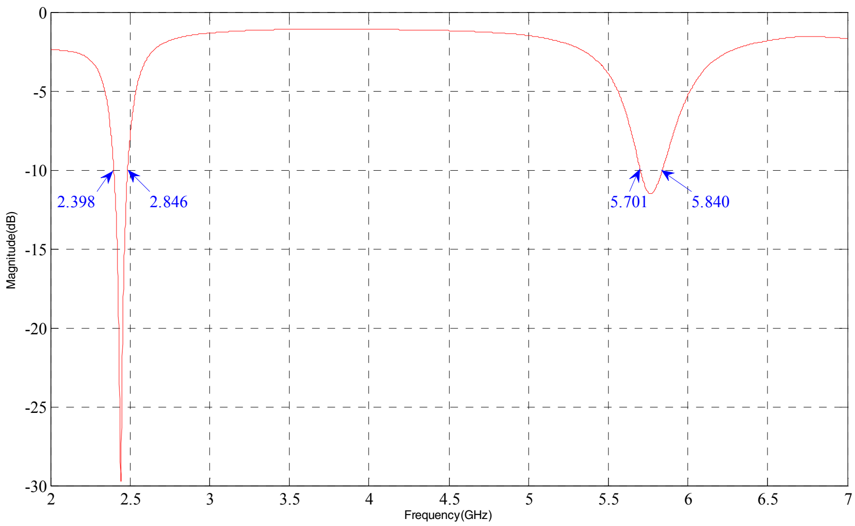
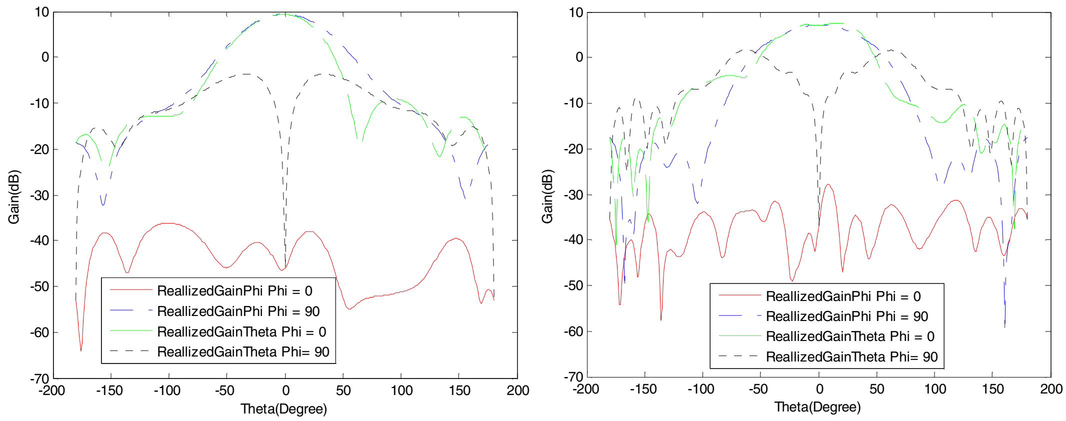


Fig.3 Simulated reflection coefficient magnitude (S_{11}, dB) of the proposed patch antenna showing dual band operation.

Simulated gain radiation patterns of the proposed antenna at the two operating bands at 2.442GHz and 5.775GHz are shown in Fig. 4, respectively. From Fig.4, we can find that antenna's maximum gain at 2.442GHz is 9.7dBi in broadside direction. At 5.775GHz, it is 7.88dBi. It can also be observed that, the radiation patterns in both bands are almost the same considering co- and cross- polarization components. Both bands maintain the same polarization.

As shown in Fig.1, in order to achieve acceptable impedance matching, the widths of inner rectangular patch and outer rectangular loop in $\varphi = 0^{\circ}$ are bigger than their length in $\varphi = 90^{\circ}$. This results in wider 3dB beamwidth in $\varphi = 90^{\circ}$ plane than the $\varphi = 0^{\circ}$ plane, as shown in Fig. 4(a-b) for both 2.4GHz and 5.8GHz bands. From Fig.4, clear deterioration at $\theta = 65^{\circ}$ is observed when antenna operates at 2.4GHz. Similarly, when antenna operates at 5.8GHz, deterioration appears at $\theta = 65^\circ$. This is because length of bridge connected isn't long enough. The shorting pin placed in the connecting bridge deteriorates directional pattern at both bands. The cross-polarization component in $\varphi = 90^\circ$ cut is higher and becomes worst for 5.8GHz. However, this is not an important component for WLAN communication applications.



(a) (b)

Fig. 4: Gain radiation pattern of the proposed antenna at: (a) 2.4GHz and (b) 5.8GHz.

4. Conclusions and Future Study

This paper presents a novel compact single layer and feed dual-band patch antenna, which operates at 2.4GHz and 5.8GHz bands simultaneously with almost symmetrical radiation pattern. For the introduction of rectangular notch, the antenna is miniaturized by 31.8% compared to a conventional rectangular patch. This antenna can be used in Wireless Local Area Network (WLAN) communications. This antenna is expected to be used with frequency selective surfaces (FSS) for achieving further high gain. These results are not included here for the sake of brevity and will be presented during the symposium in addition to the experimental results.

Acknowledgments

This work was performed at Antenna and Microwave Lab (AML), San Diego State University and was supported by the Fundamental Research Funds for the Central Universities and China Scholarship Council.

References

1. C. Balanis, "*Antenna Theory, Analysis, and Design*", Third Edition, New York: Wiley, 2005.

2. B. Li and K. W. Leung, "Dielectric-covered dual-slot antenna for dual band applications," *IEEE Trans. Antennas Propag.*, vol. 55, no. 6, pp.1768-1773, Jun. 2007

3. M. Ali, T. Sittironnarit, H. S. Hwang, R. A. Sadler, and G. J. Hayes, "Wideband/dual-band packaged antenna for 5-6GHz WLAN application," *IEEE Trans. Antennas Propag.,* vol. 52, no. 2, pp. 610-615, Feb. 2004

4. S. C. Pan and K. L. Wang, "Dual-frequency triangular microstrip antenna with a shorting pin," *IEEE Trans. Antennas Propag.,* vol. 45, no. 12, pp. 1889-1891, Dec. 1997.

5. S. M. Kim, J. M. Son, H. J. Kim and W. G. Yang, "Design and Implementation of Dual-Band Square Patch Antenna for Wireless LAN of 2.4GHz and 5.7GHz," *Asia-Pacific Conference Proceedings*, vol. 5, pp. 1-4, Dec. 2005.

6. S. H. S. Esfahlani, A. Tavakoli and P. Dehkhoda, "A Compact Single-layer Dual-band Microstrip Antenna for satellite applications," *IEEE Antennas and Wireless Propag. Letter*, vol. 10, pp. 913-934, Dec. 2011.