Shorted-slots loaded patch antenna for dual-ISM band WLAN applications

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Abstract: A novel patch antenna loaded with shorted-slots is proposed and analyzed in this article. The radiated patch antenna was chiseled two cross-slots, there are shorted-lines to be set at the middle- and cross-points of slots, which is designed to be operated at dual-ISM band (2.4 GHz and 5.8 GHz bands). A prototype of the proposed antenna with 63 mm in length, 7.6 mm in height and 72 mm in width is fabricated and experimentally investigated. The experimental results indicate that the VSWR ≤ 2.5 bandwidths achieved were 13.3% and 15.9% at 2.45 GHz and 5.5 GHz, respectively. There is good agreement between the simulated and measured results.

Keywords: patch antenna, shorted-slots, dual-ISM band, cross-slots, shorted-lines

Classification: Antennas and Propagation

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1 Introduction

In the wireless home networking arenas, through the FTTA (fiber to the antenna) technology, to combine AP (access point) and router into the lighting lamps is a trend. Hence, the patch antenna has at this state proved to be the most promising candidate, to be mounted on the ceiling transmitting and receiving signal. The wireless local area network (WLAN) is the popular wireless system which operating at the dual-ISM band: 2.4–2.5 GHz and 5.15–5.85 GHz. Therefore, the antenna is required to operate at least two bands in a WLAN system. In the literature [1] presents by chiseling slots on the patch radiator to increase operating bands, but the bandwidth is not enough in the upper-operating band. In the literature [2], to chisel the cross-slot on the patch radiator will increase the operating bandwidth, but just resonant single band. In the literatures [3, 4, 5], there are also many slots structure could resonant multi-bands, however, the operating bandwidth could not meet the requirement of the dual-ISM band system spec. In literature [6, 7] by using the stacked structure combines the slot loaded method to increase operating bandwidth, but which will result in greater surface wave to produce diffraction at the dielectric's edge, contributing to higher cross-polarization levels. In this article, a patch antenna was chiseled two cross-slots was presented. Each slot with a shorted-line to be set at the cross- and middle-points of slot, to achieve dual-ISM band performance: lower-operating band (2.4 GHz–2.5 GHz) and upper-operating band (5.15 GHz–5.85 GHz). The feasibility of broadband dual-band operating has been proven by the design of cross-slots and shorted-line on the patch radiator. The designs and analysis results will be described in detail in the next sections.

2 Antenna structure and design

The geometry of the proposed patch antenna loaded with shorted slots is shown in Fig. 1. The antenna structure comprises two substrates: the first layer substrate is a feed substrate, and the second layer is a ground-plane (length L_g and width W_g), both of them have the same size and are printed on a 1.6 mm-thick FR4 glass epoxy substrate (the relative permittivity ϵ_r is 4.3). The microstrip patch radiator (length L and width W) is printed on the top-side of the first layer. In addition, because of the antenna size is to be limited, the meandered structure was used to reduce the length of the quarter wave-length impedance transformer of the feed-line. The slots (which with length SL and width SW) are be chiseled from the surface of the patch-radiator, respectively. The shorted-line was be setup at the slots, which will change the direction of current flow and it turns a contra-direction current flow into a co-direction current around the slots, to produce the wide bandwidth and good

can be obtained across an extended bandwidth. Detail results will be presented and discussed in the next section.

3 Experimental results and discussion

The proposed dual-band antenna with dimensions is shown in the Fig. 1(a), it is fabricated to operate in the range of a dual operating-band: lower-operating band (2.4 GHz–2.5 GHz) and upper-operating band (5.15 GHz–5.85 GHz), where h is 7.6 mm. Based on the experimental studies, the optimal horizontal-slot location is set at middle of the patch-width (W), and the two optimal vertical-slots location are set at middle of the half of patch-length ($L/2$) [1]. The feasibility of broadband dual-band operating will be proven by the design of two cross-slots and shorted-line on the patch radiator by experimentally study, as shown in the Fig. 2. In the experiment, the feeding mini-coaxial with length 10 cm, and a $50\ \Omega$ I-Pex connector. Fig. 2(a) shows the measured and simulated VSWR plot of the proposed antenna, and the $VSWR \leq 2.5$ bandwidths are 325 MHz (13.3%) and 875 MHz (15.9%) at 2.45 GHz and 5.5 GHz, respectively. The simulated results are obtained by using the simulation software Ansoft HFSS. There is good agreement between the simulation and measurement results. Fig. 2(b) shows four patch radiators which have different slots structure, they are denoted as: Case I: one cross-slot, Case II: two cross-slots, Case III: two cross-slots and the shorted-line is set at the cross-points, Case IV: two cross-slots and the shorted-line is set at the middle of slots. Those four structures are presented to compare with the proposed antenna (there are two cross-slots, and the shorted-line is set at the cross- and middle-points of slots) on the performance of operating bandwidth. Fig. 2(c) shows the measured VSWR of the proposed antenna compares with the other four antennas which have different slots structure on the patch radiator. It can be seen, when increasing the cross-slot number will increase the operating bandwidth of the upper-band, and let the frequency shifting to higher frequency. Moreover, to add the shorted-line at the cross-points or middle-point of slots, which will increase the lower operating bandwidth, and it is also to let the frequency shifting to higher frequency in the upper band. When adding the shorted-line at the cross- and middle-point of slots, which will introduce a wide upper- and lower-operating bandwidth to match at dual-ISM band.

(a) Measured and simulated VSWR against frequency of the proposed antenna.

(b) Four different slots structure for comparison with the proposed antenna.

(c) Measured VSWR against frequency in terms of four different slots structure

Fig. 2. Broadband dual-band operating by the design of two cross-slots and shorted-line on the patch radiator.

The radiation features of the proposed antenna are shown in the Fig. 3. The measured 2-D and 3-D radiation patterns in the free space at 2.45 GHz and 5.5 GHz in the y-z plane (E-plane) and x-y plane (H-plane) are shown in the Fig. 3(a) and 3(b), respectively. In the 2.45 GHz case, the characteristics of radiated pattern are: the maximum gain is 8.4 dBi, the maximum cross-polarization level is about 15 dB, and the 3 dB beamwidth is $78^\circ \times 84^\circ$ in the E-plane and H-plane. In the 5.5 GHz case, the features of quasi-patch array antenna is shown, the maximum gain is 7.02 dBi, the maximum cross-polarization level is about 10 dB, and the 3 dB beamwidth is $66^\circ \times 78^\circ$ in the E-plane and H-plane. The maximum cross-polarization level in the 5.5 GHz is lower than the 2.45 GHz, that is because the printed patch jointly with shorted cross-slots will excite some undesired higher order

modes in the upper operating band, to let the cross-polarization radiation increasing, which could also cause some data rate transfer distortions. The comparison results of slotted patch radiator with and without shorted-line are also shown in the Fig. 3(c). The corresponding simulated current distributions, and the measured maximum gains are also presented. It is obviously that the shorted-line of slots turn an opposite-direction current flow into a co-direction current flow around the two cross-slots, to let the maximum gain increase in the lower-operating band. But, in the upper-operating band, the current distribution in each slot is not equal and opposite-direction, more variations in the radiation pattern are observed. This is probably because the slots jointly with the shorted-line introduce multi-resonant mode in the upper-operating band, to cause the radiation pattern distortion. Fig. 3(d) shows the measured antenna gains, beamwidths and cross-polarizations within the operating bandwidth of the proposed antenna, acceptable radiation characteristic for the practical applications is obtained. The directional feature of the proposed antenna can be observed from the vertical- and horizontal-plane of the 2-D radiation patterns.

(a) Measured 3-D and 2-D radiation patterns at 2.45GHz.

(b) Measured 3-D and 2-D radiation patterns at 5.5GHz.

(c). Simulated current distribution and measured Max. gain against frequency of the slotted patch radiator with and without shorted-line.

Frequency (GHz)	Maximum Antenna Gain (dBi)	Beamwidth E-plane (°) x H-plane (°)	Maximum Cross-polarization (dB)
2.4	7.28	84° x 104°	19
2.45	8.4	78° x 84°	15
2.5	8.22	82° x 90°	17
5.15	7.21	57° x 61°	12
5.5	7.02	66° x 78°	10
5.85	6.84	62° x 90°	13

(d). Measured antenna gains, beamwidths and cross-polarizations within the operating bandwidth of the proposed antenna.

Fig. 3. The radiation features of the proposed antenna.

4 Conclusion

In this article, the proposed dual-band patch antenna with two cross-slots jointly with shorted-line is practically capable to operate at the ISM bands: 2.4 GHz–2.5 GHz and 5.15 GHz–5.85 GHz. By correctly choosing the parameters of slot and shorted-line, the $VSWR \leq 2.5$ bandwidths achieved were 13.3% and 15.9% at 2.45 GHz and 5.5 GHz, respectively. The wide bandwidth operation has been proven by the design of the slots which was chiseled on the patch. The current distribution around the slots was turned a contra-direction into a co-direction by the shorted-line. As a result, the proposed antenna with good radiated gain can be obtained. The proposed antenna can be easily implemented to various AP and router as a compact external antenna.

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