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A Dual-Band Bow-Tie-Shaped CPW-Fed Slot Antenna for WLAN Applications

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Abstract—A dual-band bow-tie-shaped CPW-fed slot antenna design for wireless communication applications is proposed. The antenna consists of a signal strip, two conducting strips and bow-tie-shaped slots. With simple tuning geometrical parameters, the proposed antenna is suitable for WLAN 2.4/5.2/5.8 GHz bands. This antenna is designed on a single-layer PCB FR4 substrate with permittivity $\varepsilon r = 4.4$, loss tangent $\tan\delta = 0.0245$ and thickness $h = 1.6\,\text{mm}$. The antenna size of the radiating area and ground plane is $60 \times 45\,\text{mm}^2$. The measured results show a positive agreement with the simulated results.

1. INTRODUCTION

Recent research on antennas is very active due to the continuous demands of various wireless communications such as WLAN in the 2.4–2.4835 GHz, 5.15–5.35 GHz, and 5.725–5.852 GHz frequencies. To achieve small size, light weight, ease of fabrication and maintenance of multi-band operation, the applied antenna structures employ CPW-fed antennas because they have a relatively wide bandwidth, low-cost, feasibility for different frequency bands and compatibility with surface-mount devices. This study addresses the characteristics of a bow-tie-shaped slot antenna. Broadband CPW-fed circularly polarized antenna with machine-gun-shaped feeding line and symmetric-aperture.

Many authors have contributed significantly to the study of CPW-fed slot antennas [1–8]. In [1], the proposed broadband antennas, a new quasi-metallic-wall technique for improving the gain of CB-CPW single antenna and arrays, are presented as having desirable features for UWB applications. A simple and compact ultra wide-band (UWB) aperture antenna is obtained with a promising performance. In [2], a CPW-fed, Gaussian process (GP) regression is proposed as a structured supervised learning alternative to neural networks for the modeling of antenna input characteristics. In [3], a broadband printed CPW-fed circular slot antenna composed of a circular slot fed with a $50\,\Omega$ CPW line through a circular patch is presented. Measured results show that the proposed design offers an ultra-wide bandwidth of 143.2% (from 2.3 to 13.9 GHz). In [4], a dual-band CPW-fed hybrid antenna consisting of a 5.4 GHz high-band inductive slot antenna and a 2.4 GHz low-band F-shaped monopole antenna is proposed. A number of CPW-fed slot antennas have been proposed [5–8].

In this paper, a new configuration for the design of a dualband antenna is proposed and implemented. Fig. 1 shows the geometrical configuration of the slot antenna. This antenna is implemented on a FR4 substrate with $\varepsilon r = 4.4$, loss tangent $\tan\delta = 0.0245$ and thickness $h = 1.6\,\text{mm}$. The antenna consists of a signal strip, two conducting strips and bow-tie-shaped slots. A $50\,\Omega$ CPW-fed transmission line is used for the antenna feed, and the gaps between the feed lines are 0.3 mm. In order to obtain a good impedance condition, the configuration of the slot antenna is derived by tuning the geometrical parameters (h and t). The proposed design procedures are for specified frequencies and can be validated by simulation and measurement. This paper is organized as follows. Section 2

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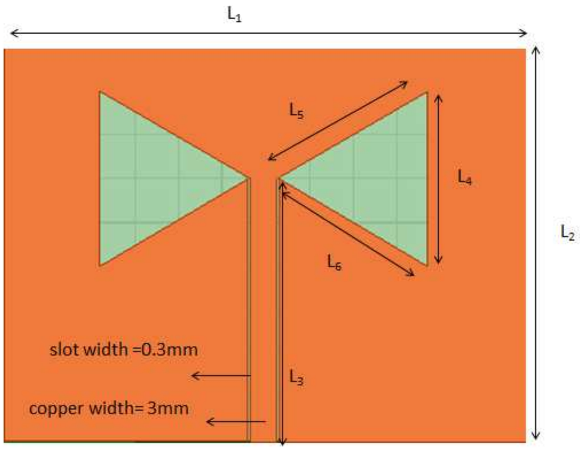


Figure 1. Bow-tie-shaped slot antenna; $L_1 = 60$, $L_2 = 45$, $L_3 = 30$, $L_4 = L_5 = L_6 = 20$ (unit: mm).

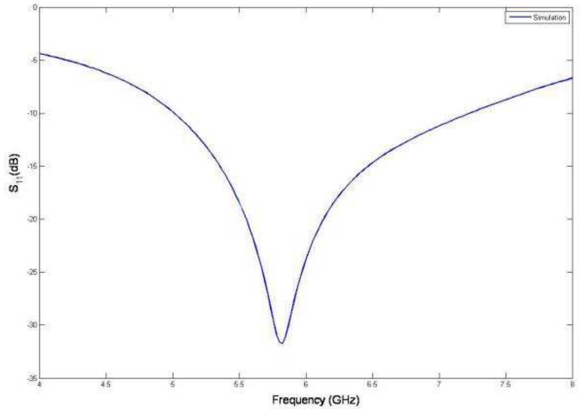


Figure 2. The simulated S_{11} (dB) of bow-tie-shaped slot antenna.

describes design procedures and discusses the simulated results for the dual-band slot antenna. Section 3 briefly describes and discusses the experimental and simulated results for the proposed antenna. Finally, Section 4 briefly draws some conclusions.

2. ANTENNA STRUCTURE AND DESIGN

The bow-tie-shaped slot antenna is devised within bandwidth ranges which cover the 5.2/5.8 GHz (WLAN) bands. In this section, the design procedures of the antenna include some parameter tuning, which can enhance the bandwidth of this antenna. Fig. 2 shows the simulated results, S_{11} (dB), of the antenna. For the simulated results, the -10 dB bandwidth of the antenna is 1.94 GHz (5.08–7.02 GHz), and the bandwidth can cover the operating frequency band of WLAN 5.2/5.8 GHz.

Adding two extra bow-tie-shaped conducting strips, h obtains a resonant frequency at 2.4 GHz (WLAN) of the antenna and maintains good impedance and stable radiation characteristics. Fig. 3 shows the configuration of the geometric parameter tuning. When h is used as the parameter for adjustment, it optimizes the lower frequency band bandwidth and return loss. The simulated results of parameter h vary from 16 to 19 mm and are shown in Fig. 4. In the simulated results, the h adjustment

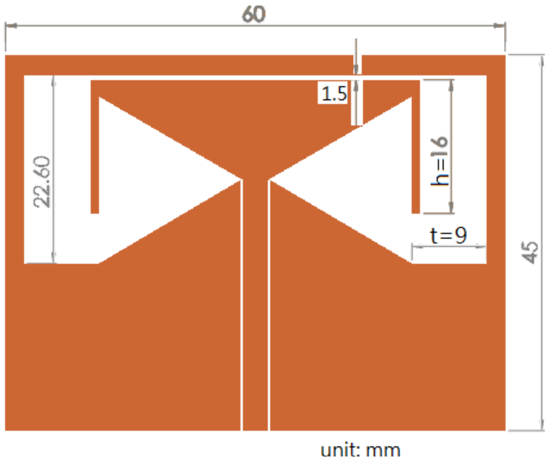


Figure 3. The configuration of a dual-band bow-tie-shaped slot antenna.

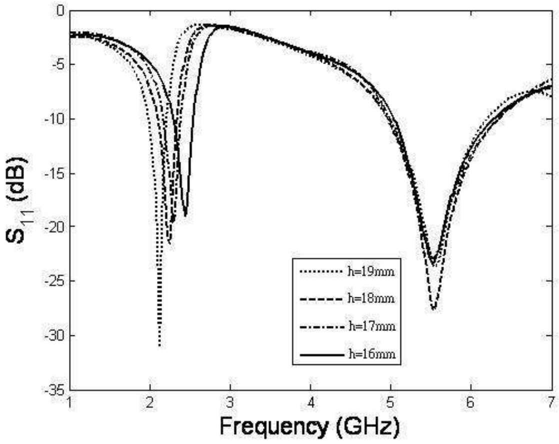


Figure 4. The simulated S_{11} (dB) of the tuning h.

results show that the upper frequency band ranges are approximately identical. However, varying the geometrical parameter h does not affect the upper frequency band, although strong effects on the excited resonant modes in the lower frequency band can be observed. When $h = 16$ mm, the lower frequency band range of the antenna is from 2.3 to 2.53 GHz (230 MHz), and the upper frequency band range of the antenna is 5.05 to 6.31 GHz (1.26 GHz). The lower frequency band return loss is 18.3 dB, and the upper frequency band return loss is 23.2 dB. However, when $h = 17$, 18 and 19 mm, the center frequency of the lower frequency band drifts towards the lower frequency band. As a result, $h = 16$ mm is selected as the optimum parameter.

Figure 5 shows the simulated results of the tuning parameter t. The simulated results of parameter t, which vary from 5.5 to 9 mm, are shown in Fig. 5. The simulation results show that the proper choice of parameter t is important in the proposed antenna. At 9 mm, the lower frequency band range of this antenna is 2.17–2.5 GHz and the upper frequency band range is 4.98–6.31 GHz. The lower frequency band return loss is 21.1 dB and the upper frequency band return loss is 24 dB. However, when $t = 5.5$ or 7.5 mm, the center frequency of the lower frequency band drifts towards the upper frequency band. The effects on the excited resonant modes in the lower frequency band can be seen clearly. In this study, the optimum t is determined to be 9 mm when using the simulated results of return loss. The simulated current distribution of the proposed antenna at 2.45 GHz is shown in Fig. 6. The antenna is obtained by adjusting the size of the parameters h and t to produce the required frequency response characteristics. The strongest power of the current distribution at 2.4 GHz is mainly in the signal strip and both sides of bow-tie-shaped conducting strip. As a result, the tuning parameters h and t are used to generate another 2.4 GHz frequency band. The simulated results clearly verify the validity of the study. By selecting appropriate sizes for h, t, good impedance matching of the CPW-fed slot antenna can be obtained.

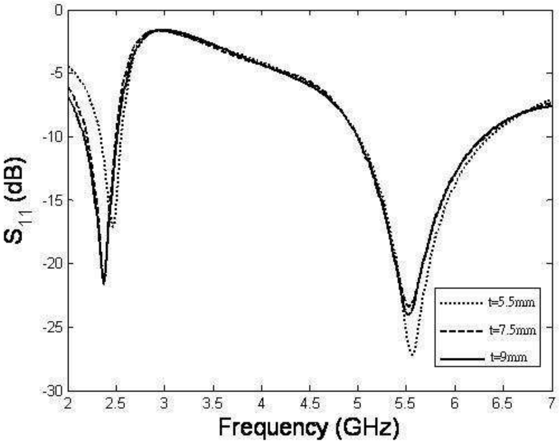


Figure 5. The simulated S_{11} (dB) of the tuning t.

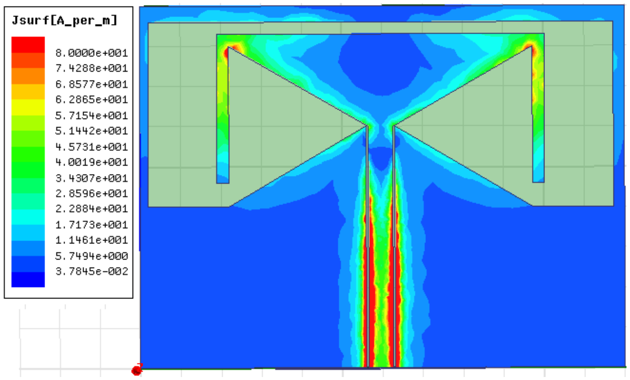


Figure 6. The current distribution of the proposed antenna at 2.45 GHz.

3. MEASUREMENT RESULTS

Figure 7 shows the physical layout of the proposed antenna, which is built on FR4 substrate having a thickness of 1.6 mm, a relative dielectric constant of 4.4 and a loss tangent $\tan\delta = 0.0254$. The proposed physical antenna size in the study is $60 \times 45\,\text{mm}^2$. We measured the return loss using an Agilent N5230A network analyzer. The simulated and measured return loss of the proposed antenna is shown in Fig. 8. The simulated results were determined using the electromagnetic simulation software of the Ansoft HFSS (High Frequency Structure Simulator).

For the simulated and measured results, the simulated -10 dB bandwidth of the antenna was found to be 0.33 GHz (2.17–2.5 GHz) in the lower frequency band and 1.32 GHz (4.98–6.31 GHz) in the upper frequency. The measured -10 dB bandwidth of the antenna is 0.31 GHz (2.26–2.57 GHz) in the lower

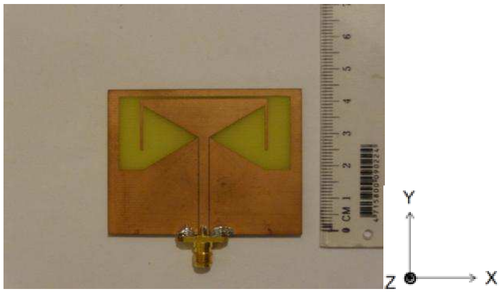


Figure 7. The photo of the fabricated bow-tie-shaped slot antenna.

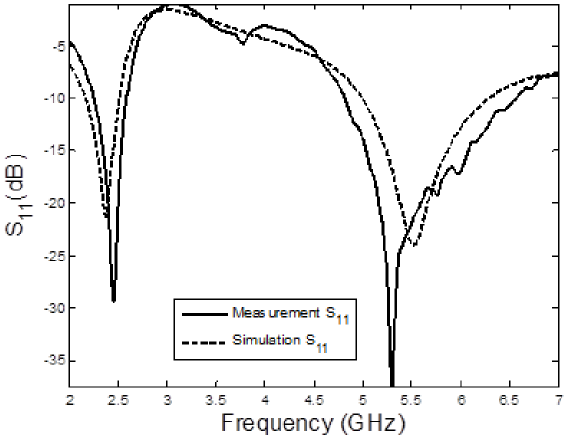
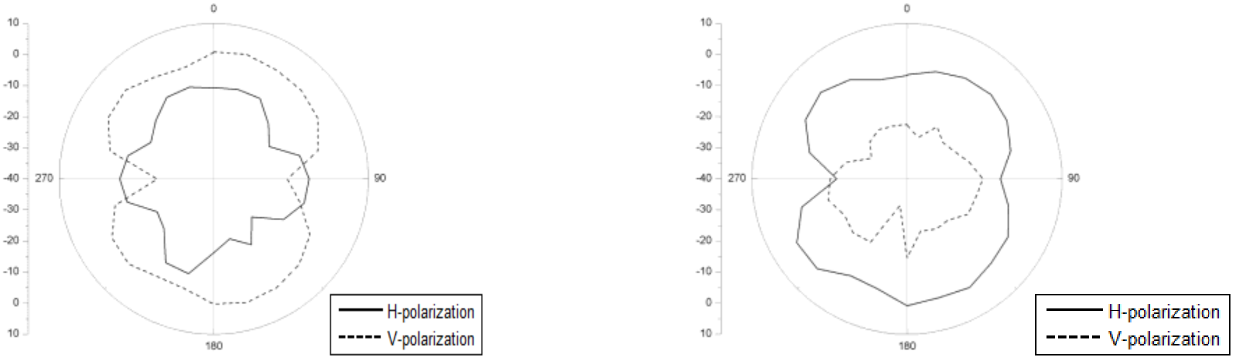
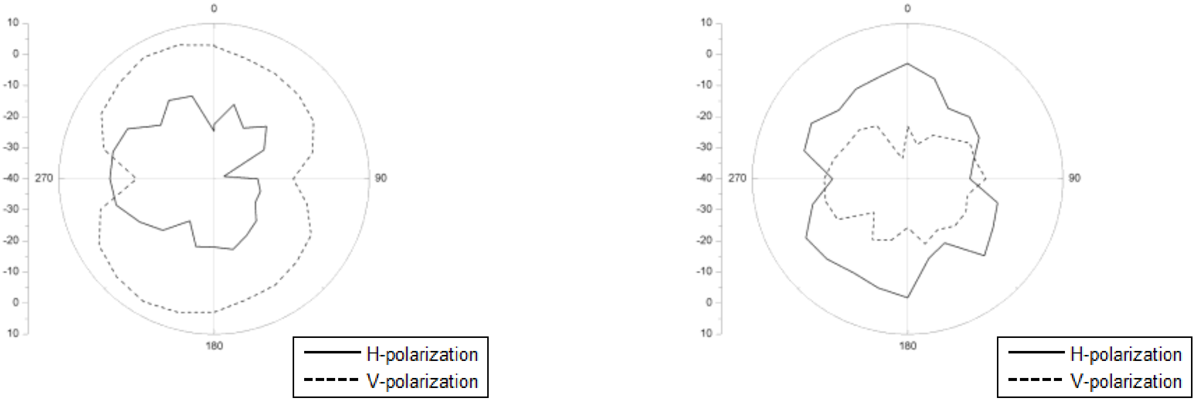


Figure 8. The simulated and measured S_{11} (dB) of the proposed slot antenna.



2.45GHz *E*-plane (*y*-*z* plane)

2.45GHz *H*-plane (*x*-*z* plane)



5.3 GHz *E*-plane (*y*-*z* plane)

5.3 GHz *H*-plane (*x*-*z* plane)

Figure 9. Measured radiation patterns at 2.45 and 5.3 GHz.

frequency band and 1.75 GHz (4.81–6.56 GHz) in the upper frequency band. The measured return loss sink in the 2.4 GHz band (WLAN) is about 29.8 dB and in the 5.2 to 5.8 GHz (WLAN) band is about 38.3 dB. The measured results are in positive agreement with the simulated results. In addition, by using the described design method, a dual-band antenna was developed to cover the WLAN 2.4/5.2/5.8 GHz operation bands.

The measured far-field co-polarization and cross-polarization radiation patterns of the proposed slot antenna at the two typical frequencies are presented in Fig. 9. In the *H*-plane (*x*-*z* plane), the radiation pattern is nearly omni-directional at the lower and upper frequency bands (2.45 and 5.2 GHz). In the *E*-plane (*y*-*z* plane), the radiation pattern is nearly bidirectional at the lower and upper frequency bands. An acceptable and stable radiation pattern for the dualband application was obtained for the proposed antenna. Table 1 shows the measured peak gain, efficiency and frequency bands for the proposed antenna. The measured peak gain with 2.45/5.3 GHz bands was obtained for the proposed antenna. The highest gain for the proposed antenna is about 3.65 dBi at 5.3 GHz and the highest efficiency is at about 80.27% at 2.45 GHz.

Table 1. Gain and radiation efficiency.

Freq (GHz)	Gain (dBi)	Total Rad. Efficiency (%)
2.45	2.55	80.27
5.3	3.65	75.54

4. CONCLUSIONS

A novel dual-band configuration of a CPW-fed slot antenna using a signal strip, two conducting strips and bow-tie-shaped slots has been proposed and implemented. The influences of the two geometrical parameters on the antenna have been studied. With simple tuning parameters, the proposed antenna is suitable for WLAN 2.4/5.2/5.8 GHz operation bands. The measured results show a positive agreement with simulated results.

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