

## DUAL-WIDEBAND BOX-SHAPED ANTENNA WITH A U-SHAPED SLOT

L. Jin, X. M. Zhang, Z. Zhang, R. Guan, and B. Yang

National Key Laboratory of Science and Technology  
on Antennas and Microwaves  
Xidian University, Xi'an, Shaanxi 710071, China

**Abstract**—In this paper, a study on the dual-frequency box-shaped antenna is presented. With a 5-branch feeding strip and two plates of shorting strips, the antenna shows broadband and compact property. Then a U-shaped slot is etched for dual-band operation. Simulated and measured results all show that this antenna exhibits dual-wideband characteristic, covering several present wireless communication systems, such as GSM800/900 (824–960 MHz), WLAN11b (2.4–2.5 GHz), WiMax802.16 (2.5–2.7 GHz), and Bluetooth band (2.4–2.8 GHz). The simulated impedance bandwidth (2 : 1 VSWR) is 21.5% and 37.2% in the lower and higher band, ranging from 790 MHz–980 MHz and 2.3 GHz–3.35 GHz. Then details of the antenna are described and the prototype is fabricated and tested. A measured bandwidth of 19.8% and 38.9% in the two bands, ranging from 820 MHz–1000 MHz and 2.28 GHz–3.38 GHz, is observed, shown good agreement with simulated results. Moreover, the antenna has a coaxial feed with a compact size of  $0.27\lambda \times 0.22\lambda \times 0.036\lambda$  ( $\lambda$  is the wavelength referenced to the lowest edge of the operating band 820 MHz).

### 1. INTRODUCTION

With the rapid developments of wireless communication, dual-band antennas are required since they allow operation in multiple frequency bands, thus eliminating the need for separate antenna for each application. The integration of different radio modules into the same device has also given a need for the dual-band antenna. There are many works reported on it. At present, dual-band planar inverted-F antennas (PIFA) [1, 2] and microstrip patch antennas (MSA) [3]

have gained a lot of interest due to their easy structure, low cost and good applicability for portable devices. However, they inherit narrow bandwidth. In [1], a bandwidth of 18.9% and 9.15% is achieved centered at 2.65 GHz and 8.20 GHz. The ground plane is as large as  $3.36\lambda_0 \times 3.37\lambda_0$  (38 mm  $\times$  37 mm). The bandwidth of [2] is 10% and 20% with a dimension of  $0.40\lambda_1 \times 0.40\lambda_1 \times 0.04\lambda_1$  ( $\lambda_0$ ,  $\lambda_1$  is the wavelength referenced to the lowest edge of the operating band). Also, different U-shaped antennas have been simulated in [3], with bandwidth not more than 10.1% in two bands. It is clearly seen that it is difficulty for them to obtain broad bandwidth in two bands while hold small size.

Due to the merits of low profile and broad bandwidth, suspended patch antennas (SPAs) have been widely used. A compact dual-wideband SPA with a U-shaped slot is introduced in this paper. It evolves from [4]. The original design realizes dual-band operation centered at 2.4 GHz, 5.2 GHz and 5.8 GHz by varying the angle of inclined ground plane. However, it is inconvenient to compute the angle and fabricate the antenna accurately. The design in this text realizes dual-band operation centered at 0.9 GHz, 2.45 GHz and 2.6 GHz using a box-shaped antenna. By employing two shorting strips [5–7], size reduction of the antenna is achieved. The dimension of the antenna is only about  $0.27\lambda \times 0.22\lambda \times 0.036\lambda$  ( $\lambda$  is the wavelength referenced to the lowest edge of the operating band 820 MHz). With addition of a U-shaped slot, dual frequency is realized. Then, a five-branch feeding strip [8] is used to broaden the bandwidth of the two bands. Dual-wideband characteristic appears. And a 19.8% bandwidth in the lower band and a 38.9% in the higher are observed, for 2 : 1 VSWR. The lower band, ranging from 820–1000 MHz, is used for GSM800/900 (824–960 MHz) band. And the higher frequency, ranging from 2.28–3.38 GHz, satisfies requirements of WLAN11b, WiMax820.16 and Bluetooth band. Compared with antennas in [1–3], the antenna in this paper is obviously compact in size and broadband in dual-frequency, thus suitable for several wireless communication systems [9, 10].

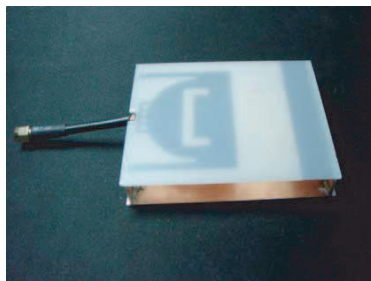
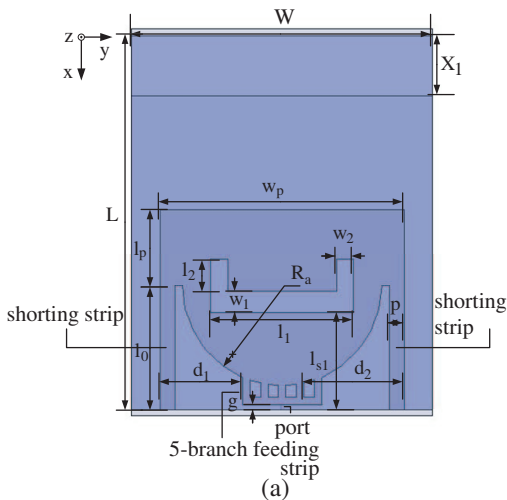
In addition to all mentioned above, it is worth noticing that the whole antenna is constructed from low cost FR4 board. Therefore, though it looks more complicated in structure than other antennas in [1–4], the fabrication of it is easier and more accurate. Also, it can be integrated with other devices thus possessing good applicability.

The dual frequency is tuned by changing the dimensions of the U-slot. A parametric study has been carried out using method of finite element-based software, Ansoft HFSS<sup>TM</sup> v11. A parameter is varied at a time, keeping others remained.

## 2. ANTENNA DESIGN

Figure 1 shows the geometry and prototype of the proposed antenna. The radiated patch, loading with a U-shaped slot, consists of a rectangular (dimensions  $l_p \times w_p$ ) and a semicircular patch (radius  $R_a$ ). It is suspended at a height of  $h$  and backed by an end-folded U-shaped wall, which consists of a horizontal ground (dimensions  $L \times W$ ), two identical vertical walls (dimensions  $W \times h$ ) and an end-folded strip of length  $X_l$ . A pair of shorting strips, with the width of  $p$  and length of  $l_0$ , is located at two ends of the radiated patch. Meanwhile, a uniform 5-branch feeding strip is employed in this design. The width of the branch equals 2 mm. Other detail variables are labeled in Fig. 1.

Two arms of the slot are identical, with length  $l_2$  and width  $w_2$ . The dual frequency is tuned by changing length, width and location of the slot.



(b)

(c)

**Figure 1.** The configuration of the proposed antenna. (a) Top view, (b) side view, (c) the photograph of the proposed antenna.

A coaxial probe feed with a diameter of 1.2 mm is used to feed the patch through feeding bridge. Thus, the probe length  $g$  is shortened, improving the impedance matching of the antenna.

To design the dual-wideband compact box-shaped SPA, the following dimensions (units: mm) are selected by simulation:  $L = 100$ ,  $W = 80$ ,  $h = 13$ ,  $X_l = 16$ ,  $l_p = 20.5$ ,  $w_p = 65$ ,  $l_0 = 33$ ,  $p = 4$ ,  $R_a = 26.5$ ,  $g = 1.5$ ,  $d_1 = 22$ ,  $d_2 = 26.75$ ,  $l_{s1} = 26$ ,  $l_1 = 38$ ,  $w_1 = 5.5$ ,  $l_2 = 8.5$ ,  $w_2 = 4.5$ ,  $h_{sub} = 1.6$ .

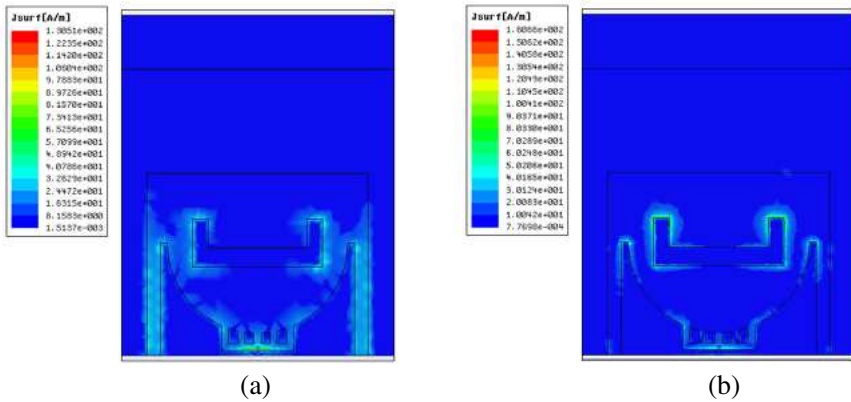
The antenna is constructed from FR4 substrate of relative permittivity 4.4, thickness  $h_{sub} = 1.6$  mm.

### 3. RESULTS AND DISCUSSIONS

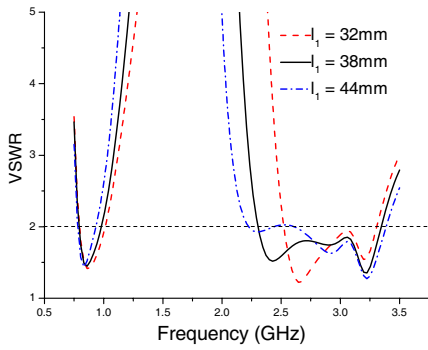
The simulated surface current distributions on the antenna at 0.85 GHz and 2.5 GHz are shown in Fig. 3. The 0.85 GHz frequency relies on the patch antenna as speculated. The higher frequency 2.5 GHz mainly depends on the U-shaped slot, especially, on two arms. And the current distribution in the higher band, as Fig. 2(b) shown, leads to a relatively large cross-polarization level in  $H$ -plane.

From the result above, the U-shaped slot plays an important role on the dual-band characteristic. From Fig. 3 to Fig. 6, we will discuss it in detail.

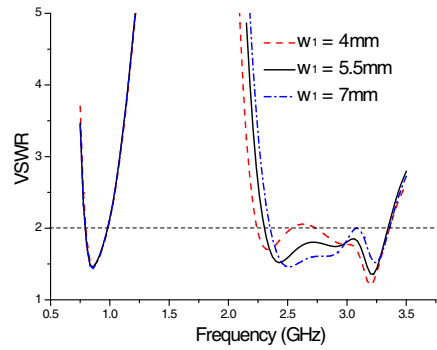
With the exception of parameter  $l_1$ , others have little effect on the lower frequency. As  $l_1$  is larger or smaller than value 38 mm, the bandwidth performance gets bad, as Fig. 3 plotted. Properly select the value of it, a dual-wideband antenna is obtained. And an optimum



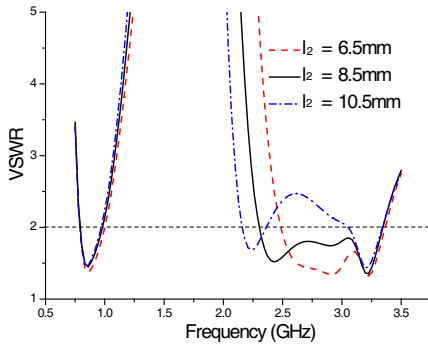
**Figure 2.** Simulated surface current distributions (a) at 0.85 GHz, (b) at 2.5 GHz.



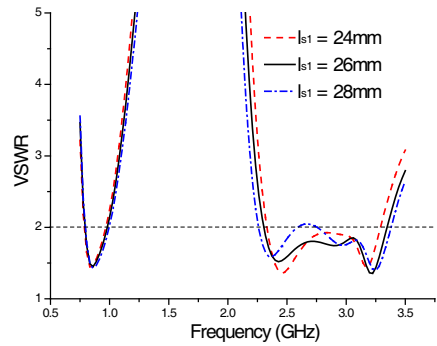
**Figure 3.** Simulated VSWR varying with  $l_1$ .



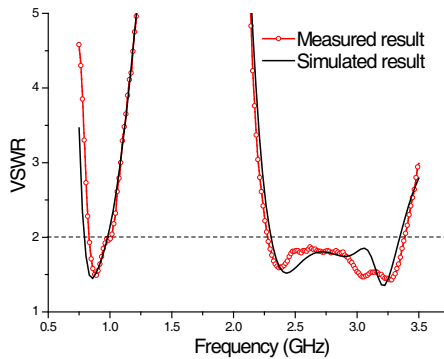
**Figure 4.** Variation of VSWR with the change of width  $w_1$ .



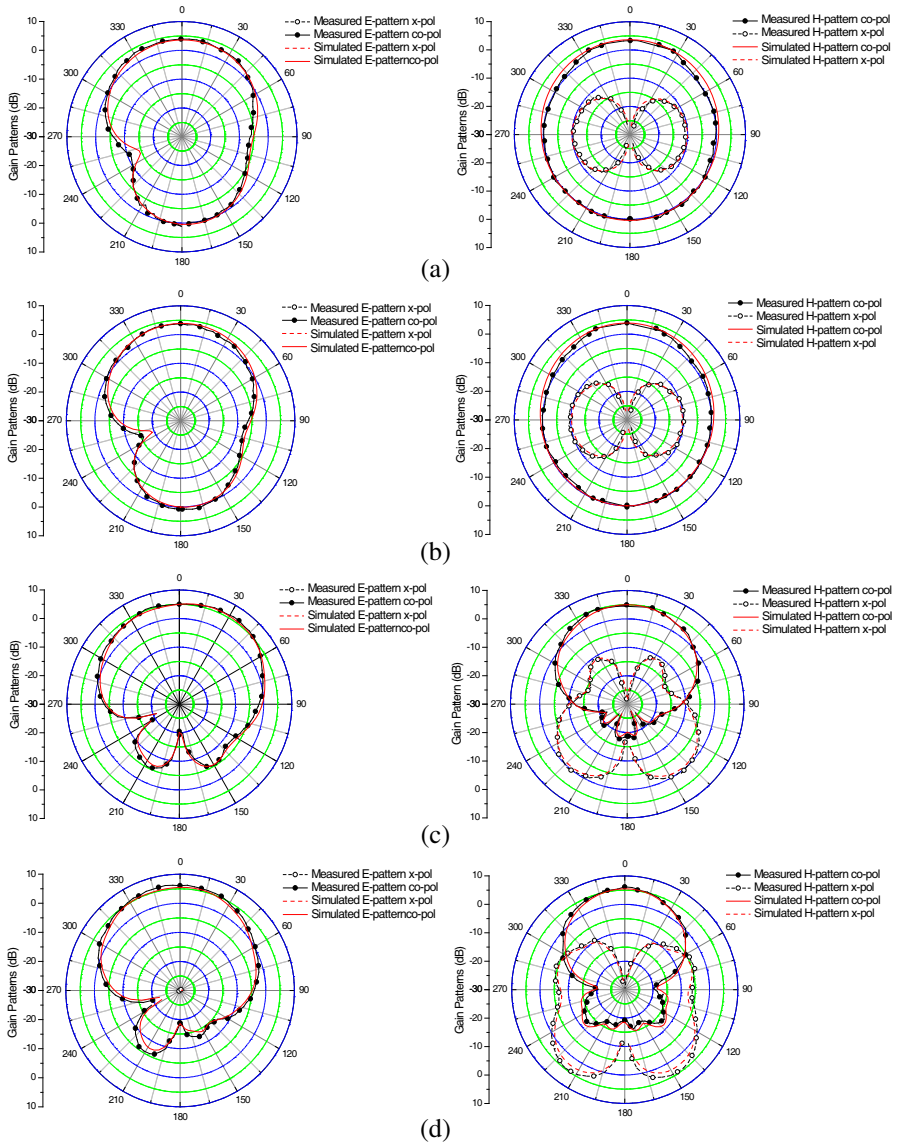
**Figure 5.** Simulated VSWR tuning by  $l_2$ .



**Figure 6.** Effect of  $l_{s1}$  on the VSWR.



**Figure 7.** Comparison between simulated and measured VSWR for the proposed antenna.



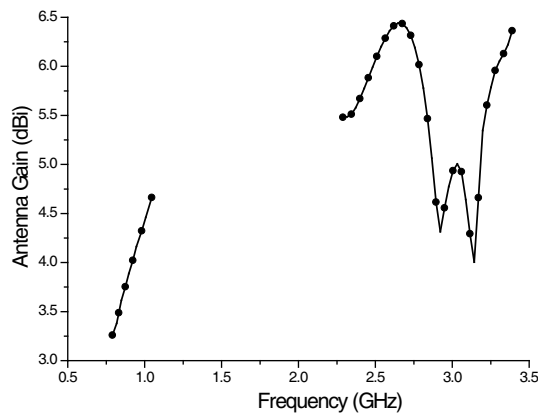
**Figure 8.** Measured and Simulated radiation patterns. (a) At 0.85 GHz, (b) at 0.90 GHz, (c) at 2.5 GHz, (d) at 2.8 GHz.

width of the slot is  $w_1 = 5.5$  mm according to the curves of Fig. 4. In addition, as Fig. 2(b) shown, current mostly distributes on two arms of the U-slot. By tuning the length of them from 6.5 mm to 10.5 mm, a

wide variation in bandwidth is achieved as seen in Fig. 5. But a notched frequency occurred at 10.5 mm. So, it is certain that  $l_2 = 8.5$  mm is the best value. Fig. 6 shows the effects of adjusting the location of the slot. It is evident that  $l_{s1} = 26$  mm is the best.

The final optimum values of the antenna parameters are demonstrated in Section 2.

The photograph of the antenna is described in Fig. 1(c). It is tested by Wiltron 37269A Network Analyzer. Simulated and measured results of VSWR are plotted in Fig. 7. The two results reasonable agree with each other. The difference between them may be caused by the inaccurate dimensions in the fabrication. The band obtained is 0.82 GHz–1.0 GHz (19.8% bandwidth) for the lower frequency and 2.28 GHz–3.38 GHz (38.9% bandwidth) for the higher frequency. The measured and simulated gain patterns at frequencies around 850 MHz, 900 MHz, 2.5 GHz and 2.8 GHz in  $E$ -plane and  $H$ -plane are shown in Fig. 8. It is noted that the cross polarization level in  $E$ -plane for all frequencies is below  $-30$  dB, which is very low. However, due to the introduction of U-slot, the cross polarization level in  $H$ -plane is relatively large in the higher band. Furthermore, the measured peak gains against frequency across the two bands are shown in Fig. 9. The obtained gains for the two bands, which are relatively higher, range from 3.2 to 4.8 dBi and 4.2 to 6.5 dBi respectively.



**Figure 9.** Measured peak gain of the proposed antenna across operating two bands.

#### 4. CONCLUSION

A box-shaped dual-wideband suspended patch antenna is introduced. The overall size is only about  $0.27\lambda \times 0.22\lambda \times 0.036\lambda$ , compact and dedicate. By employing a U-slot, dual-band characteristic appears. Then two shorting strips and a five-branch feeding strip contribute to the compact and broadband property. The dual frequency is tuned by changing the dimensions and location of the slot. And a general parametric study has been carried out by software Ansoft HFSS. Simulated and measured results agree well with each other. The bandwidth obtained is 19.8% and 38.9% in the lower and higher band. The relatively higher peak gains are also observed. Therefore, this compact dual-wideband antenna is very applicable for wireless communication systems.

#### ACKNOWLEDGMENT

The authors would like to express their thanks to the support of the NSFC of P. R. China under Grant (No. 60671056).

#### REFERENCES

1. Ren, W. and Y.-A. Liu, "Design of dual-band PIFA with U- and meanderline-shaped slots," *The 4th Asia-Pacific Conference on Environmental Electromagnetics*, 889–892, 2006.
2. Row, J.-S., "Experimental studies of the dual-band planar inverted-F antenna with a U-shaped slot," *Microwave and Optical Technology Letters*, Vol. 37, 359–361, 2003.
3. Murad, N. A., M. Esa, and S. Tukachil, "Microstrip U-shaped dual-band antenna," *Asia-Pacific Conference on Applied Electromagnetics, APACE*, 2005.
4. Chang, F. S., H. T. Chen, and P. H. Hsu, "A novel broadband antenna for WLAN application," *IEEE Antennas and Propagation Society International Symposium*, Vol. 2A, 2005, pp. 557-560.
5. Shakib, M. N., M. T. Islam, and N. Misran, "Patch antenna design for WLAN system," *Microwave Conference*, 2785–2787, 2009.
6. Mok, W. C., R. Chair, and K. M. Luk, "Wideband quarter-wave patch antenna with shorting pin," *IEE Proceedings Microwave, Antennas and Propagation*, Vol. 150, 56–60, 2003.
7. Li, Y., K. M. Luk, and R. Chair, "A wideband triangular shaped patch antenna with folded shorting wall," *IEEE Antennas and*



- Propagation Society International Symposium*, Vol. 14, 3517–3520, 2004.
8. Wong, K.-L., C.-H. Wu, and S.-W. Su, “Ultrawide-band square planar metal-plate monopole antenna with a trident-shaped feeding strip,” *IEEE Transactions on Antennas and Propagation*, Vol. 53, 1262–1269, 2009.
  9. Islam, M. T., M. N. Shakib, and N. Misran, “Multi-slotted microstrip patch antenna for wireless communication,” *Progress In Electromagnetics Research Letters*, Vol. 10, 11–18, 2009.
  10. Islam, M. T., M. N. Shakib, and N. Misran, “Broadband E-H shaped microstrip patch antenna for wireless systems,” *Progress In Electromagnetics Research*, Vol. 98, 163–173, 2009.