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Compact Dual-Band Half-Ring-Shaped Bent Slot Antenna for WLAN and WiMAX Applications

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Abstract

A compact dual-band half-ring-shaped (HRS) bent slot antenna fed by a coplanar waveguide for wireless local area network (WLAN) and worldwide interoperability for microwave access (WiMAX) applications is presented. The antenna consists of two HRS slots with different lengths and widths. The two HRS slots are connected through an arc-shaped slit, and the upper HRS slot is bent in order to reduce the size of the antenna. The optimized dual-band HRS bent slot antenna operating in the 2.45 GHz WLAN and 3.5 GHz WiMAX bands is fabricated on an FR4 substrate with dimensions of 30 mm by 30 mm. The slot length of the proposed dual-band slot antenna is reduced by 35%, compared to a conventional dual-band rectangular slot antenna. Experimental results show that the proposed antenna operates in the frequency bands of 2.40–2.49 GHz and 3.39–3.72 GHz for a voltage standing wave ratio of less than 2, and measured gain is larger than 1.4 dBi in the two bands.

Index Terms: Bent slot, Coplanar waveguide, Compact, Dual-band slot antenna, Half-ring-shaped slot

I. INTRODUCTION

There has been increasing demand for the development of a multiband antenna for mobile devices because of the development of many different wireless communications services, such as the global positioning system (GPS), the worldwide interoperability for microwave access (WiMAX), and the wireless local area network (WLAN) [1, 2]. Among various types of planar antennas, planar slot antennas have been widely used for the design of multiband antennas because of their compact size, low profile, wide bandwidth, and easy integration with other devices [3].

To create multiple resonant frequency bands on a planar slot antenna, many different techniques have been investigated. An aperture-coupled rectangular slot antenna (ACRSA) fed by an inductively coupled coplanar waveguide (CPW) feed line by using three protruded slots with different lengths was proposed for 2.30–2.46 GHz, 3.22–3.42 GHz, and 4.86–5.66 GHz bands [4]. Three monopole slots operating in their quarter-wavelength modes and a step-shaped microstrip feed line were used to generate two wide operating bands at about 900 MHz and 1,900 MHz for laptop computer applications [5]. A compact multiband slot antenna covering GSM900, DCS1800, PCS1900, UMTS, and a 2.45-GHz WLAN was developed by using T-shaped and E-shaped open-ended slots etched at the edge of the ground plane of mobile handsets [6]. A dual-band slot antenna designed by analyzing the E-field distributions and cut-off frequencies of the individual modes in a double T-stub loaded aperture was proposed for 2.45 GHz and 5 GHz

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WLAN bands [7]. An arc-shaped stub was loaded on a circular slot antenna in order to yield multiple resonant modes at 2.45 GHz and 5 GHz WLAN bands [8]. A compact tri-band H-shaped slot antenna fed by a microstrip feed line operating in 1.575 GHz GPS L1, 2.45 GHz WLAN, and 5 GHz WLAN bands was developed by using four resonant modes [9]. A miniaturized dual-band ring slot antenna loaded with interdigitated slits was designed for 2.45 GHz and 5 GHz WLAN bands [10].

In this article, a compact dual-band CPW-fed half-ring-shaped (HRS) bent slot antenna is proposed for WLAN and WiMAX applications. It is well known that in a CPW-fed slot antenna, an inductively coupled slot antenna resonates at one wavelength, whereas a capacitively coupled slot antenna operates at a half wavelength [11]. Therefore, a capacitive feed is preferred to reduce the antenna size. In the proposed antenna, a capacitive feed using a modified T-shaped stub is employed. Two aperture-coupled HRS slots are used to create two resonant frequency bands. The upper HRS slot is bent in order to reduce the size of the antenna. A step-by-step design procedure for the proposed dual-band slot antenna starting from a dual-band ACRSA is presented, along with a performance comparison of the input impedance and reflection coefficient. Note that the design parameters of the proposed antenna are optimized for the 2.45 GHz WLAN (2.40–2.485 GHz) and the 3.5 GHz WiMAX (3.40–3.60 GHz) bands. All the simulated results were obtained with the commercial electromagnetic simulator CST Microwave Studio (MWS).

II. ANTENNA GEOMETRY AND DESIGN

Fig. 1 shows the geometry of the proposed dual-band HRS bent slot antenna. It is composed of two HRS slots with different lengths and widths. The two HRS slots are connected through an arc-shaped slit, and the upper HRS slot is bent in order to reduce the size of the antenna. The outer radius and width of the lower HRS slot are R_{s1} and w_{s1}, respectively, whereas those of the upper HRS slot are R_{s2} and w_{s2}, respectively. A modified T-shaped stub is inserted inside the HRS slots to match the slot impedance with the 50-Ω CPW feed line. The length of the modified T-shaped stub is determined by angle θ_f, which is the angle between the center of the feed line and one end of the stub. The width of the stub is w_c, and the length of the center feed line extruded inside the slots is l_c. The gap between the upper and lower HRS slots is g_s. The length of the arc-shaped slit connecting the two slots is determined by angle θ_s, which is the angle between the center of the feed line and one end of the arc-shaped slit. The lengths of the bent parts of the upper HRS slot are indicated as l_1, l_2, and l_3.The width of the center conductor is w_f, and the gap between the center conductor and the ground of the CPW feed line is g_f. The antenna is patterned on an FR4 substrate with a dielectric constant of 4.4 and a thickness of h = 0.8 mm (loss tangent = 0.025).

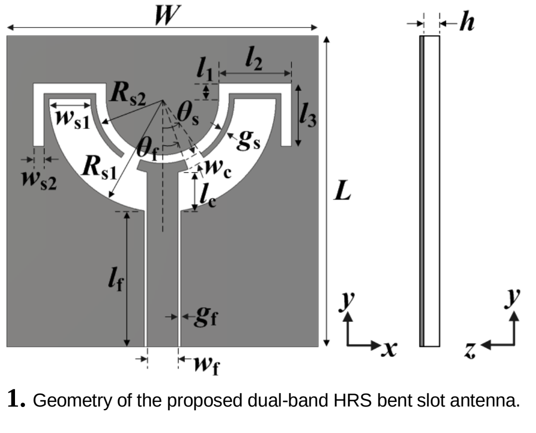
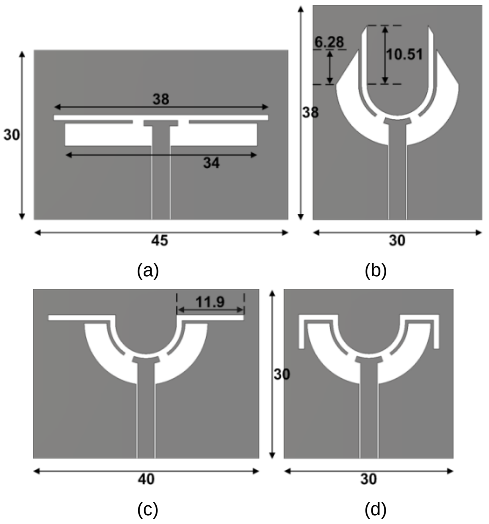


Fig. 1. Geometry of the proposed dual-band HRS bent slot antenna.

Table 1. Final design parameters of the proposed antenna

Parameter	Value (mm)	Parameter	Value (mm)
W	30	l_c	3.7
L	30	w_c	1
R_{s1}	10.9	θ_s	35°
w_{s1}	4	θ_f	20°
R_{s2}	6.4	g_s	0.5
w_{s2}	1	l_1	1.5
w_f	3	l_2	7
g_f	0.3	l_3	6.1
l_f	13	h	0.8



(a) (b)

(c) (d)

Fig. 2. Design procedure for the proposed dual-band slot antenna: (a) conventional dual-band ACRSA, (b) half-ring-wise rounded dual-band ACRSA, (c) bent half-ring-wise rounded dual-band ACRSA, and (d) proposed dual-band bent slot antenna.

The length and width of the substrate are indicated as *L* and *W*, respectively. The final design parameters of the proposed antenna are summarized in Table 1.

Four antenna structures considered for performance comparison in the design procedure are presented in Fig. 2, and the corresponding simulated input impedance, reflection coefficient, and gain characteristics for the four antenna structures are shown in Fig. 3.

First, a CPW-fed dual-band ACRSA with a T-shaped stub, which is used as a reference antenna, as shown in Fig. 2(a), was designed for the 2.45 GHz WLAN and 3.5 GHz WiMAX bands by optimizing the dimensions of the rectangular slot and the T-shaped stub. The length and width of the lower rectangular slot are 34 mm and 4 mm, respectively, whereas those of the upper slot are 38 mm and 1 mm, respectively. The length and width of the antenna are 30 mm and 45 mm, respectively. We can see from Fig. 3 that the first and second frequency bands for a voltage standing wave ratio (VSWR) <2 are 2.38–2.58 GHz and 3.50–3.54 GHz, respectively. It is worthwhile to note that the first band is wider than the second, and it can cover the 2.45 GHz WLAN band (2.40–2.485 GHz). The gains of the first and second bands are 2.7 to 3.3 dBi and -7.3 to -0.8 dBi, respectively. However, the second band is very narrow, and cannot fully cover the 3.5 GHz WiMAX band (3.40–3.60 GHz). Furthermore, the gain in this band is lower than 0 dBi.

Secondly, a half-ring-wise rounded dual-band ACRSA was designed, as shown in Fig. 2(b). The shapes of the slots were modified to keep the coupling gap length between the two slots. In this case, the length of the antenna was increased to 38 mm, and the width decreased to 30 mm. We can see that the frequency band for a VSWR <2 exists only at 2.37–2.49 GHz, because impedance matching on the second band deteriorates. The gain in the first band is 1.7–2.0 dBi.

Thirdly, the half-ring-wise rounded dual-band ACRSA was further modified by bending the upper slot, as shown in Fig. 2(c). In this case, the length of the antenna was decreased to 30 mm and the width increased to 40 mm. The first frequency band for a VSWR <2 is 2.39–2.49 GHz, but the second band moves towards a high frequency of 3.71–3.84 GHz because the coupling gap length between the two slots was reduced. The gain in the first band is 1.9–2.5 dBi, whereas that of the second band is 2.3–2.9 dBi.

Finally, the proposed dual-band HRS bent slot antenna was obtained by bending the upper slot one more time, as shown in Fig. 2(d). The length and width of the antenna are 30 mm and 30 mm, respectively. The first and second frequency bands for a VSWR <2 are 2.40–2.49 GHz and 3.40–3.62 GHz, respectively, which satisfy both the 2.45 GHz WLAN and 3.5 GHz WiMAX bands. The gains of the first and second bands are 1.5–2.3 dBi and 2.1–2.9 dBi, respectively. Note that the impedance bandwidth and gain in the first band of the proposed antenna is decreased compared to the conventional dual-band ACRSA, whereas those in the second band are extensively increased.

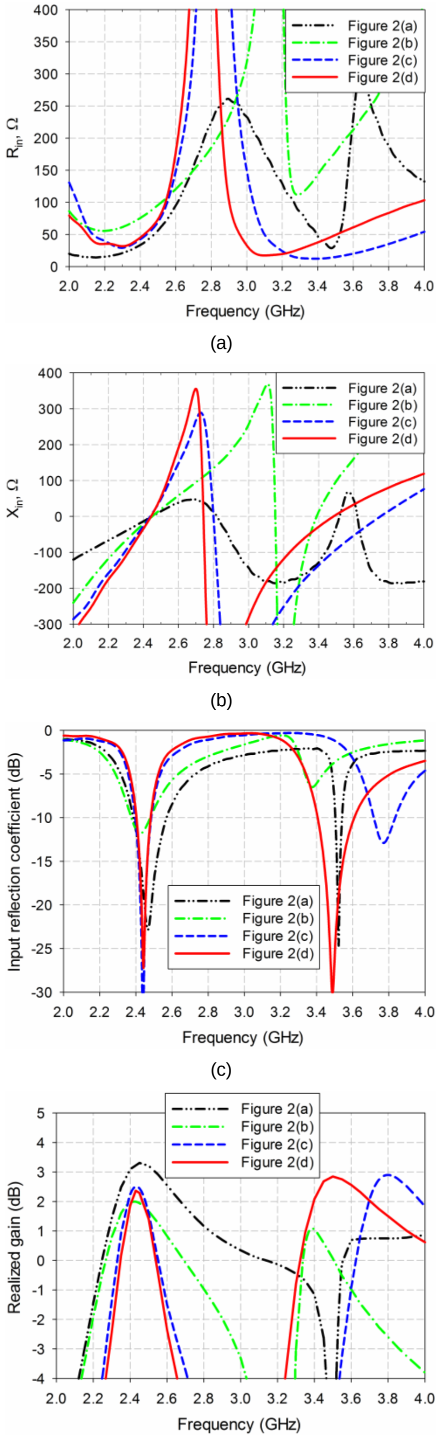
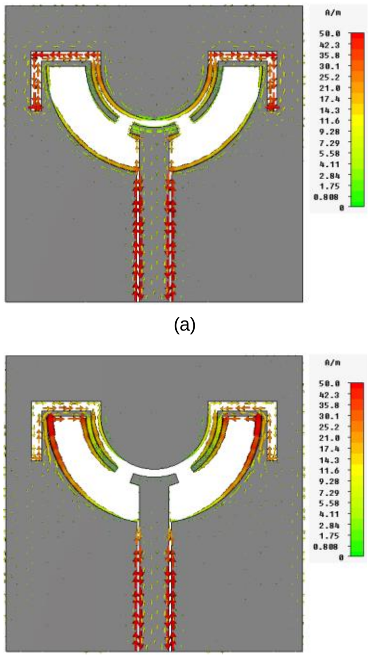


Fig. 3. Performance comparison of the four antenna structures in Fig. 2: (a) resistance, (b) reactance, (c) reflection coefficient, and (d) gain.

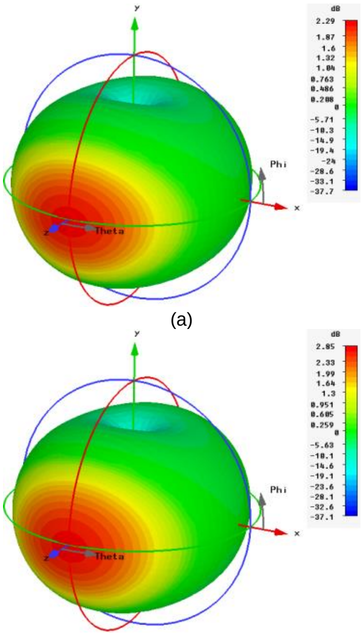
The simulated surface current distributions of the proposed dual-band slot antenna at 2.45 GHz and 3.5 GHz are shown in Fig. 4. We can see from Fig. 4 that the surface currents are strong on the upper slot at 2.45 GHz, whereas they are mainly distributed on the lower slot with some coupling on the upper slot at 3.5 GHz.



(a)

(b)

Fig. 4. Simulated surface current distributions at (a) 2.45 GHz and (b) 3.5 GHz.



(a)

(b)

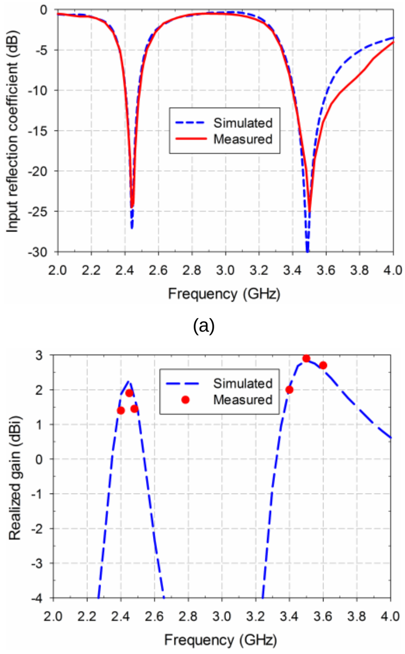
Fig. 5. Simulated radiation patterns at (a) 2.45 GHz and (b) 3.5 GHz.

Fig. 5 shows the simulated three-dimensional radiation patterns of the proposed dual-band slot antenna at 2.45 GHz and 3.5 GHz. The patterns show a typical nearly omni-directional pattern with a broadside maximum direction (±z-direction).

III. EXPERIMENTAL RESULTS

Based on the study of the design procedure previously described, a prototype of the proposed dual-band HRS bent slot antenna was fabricated on an FR4 substrate. A photograph of the fabricated antenna is in Fig. 6.

Fig. 6. Photograph of the fabricated antenna.



(a)

(b)

Fig. 7. Measured performance of the fabricated antenna: (a) reflection coefficient and (b) realized gain.

The simulated and measured input reflection coefficient and gain characteristics of the fabricated antenna are presented in Fig. 7. An Agilent N5230A network analyzer was used to measure the input reflection coefficient and realized gain. As shown in Fig. 7(a), the simulated frequency bands for a VSWR < 2 are 2.40–2.49 GHz and 3.40–3.62 GHz, respectively, whereas the measured bands are 2.40–2.49 GHz and 3.39–3.72 GHz, respectively. The simulated gain of the fabricated antenna ranges between 1.5 dBi and 2.3 dBi in the first band and between 2.1 dBi and 2.9 dBi in the second band, whereas the measured gain ranges from 1.4 dBi to 1.9 dBi in the first band and from 2.0 dBi to 2.9 dBi in the second band. Good agreement is observed between the measured and simulated results. It is worthwhile to note that the proposed dual-band HRS bent slot antenna satisfies the frequency band requirements of both the 2.45 GHz WLAN and 3.5 GHz WiMAX bands, and the horizontal-direction slot length of the proposed antenna is reduced by 35%, compared to that of the conventional dual-band ACRSA.

The measured radiation patterns of the proposed dual-band slot antenna in the y-z and z-x planes at 2.45 GHz and 3.5 GHz are compared to those of the simulated ones in Fig. 8. The simulated and measured patterns agree well with each other, and the patterns are similar to those of a typical slot antenna.

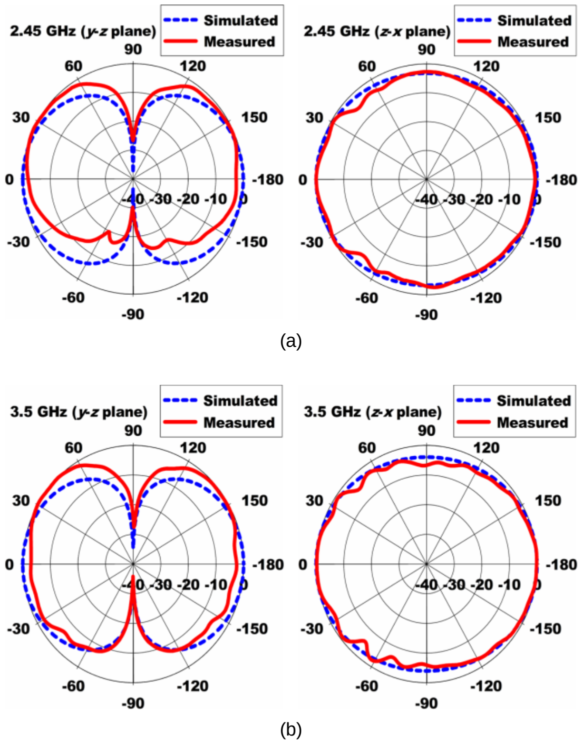


Fig. 8. Measured radiation patterns of the fabricated antenna in y-z and z-x planes at (a) 2.45 GHz and (b) 3.5 GHz.

IV. CONCLUSION

A design method for a compact CPW-fed dual-band HRS bent slot antenna for WLAN and WiMAX applications has been presented. The proposed antenna consists of two HRS slots with different lengths and widths. The two HRS slots are connected through an arc-shaped slit, and the upper HRS slot is bent in order to reduce the size of the antenna. A capacitive CPW feed using a modified T-shaped stub is employed to further reduce the antenna size. A systematic design procedure for the proposed antenna is explained, and a performance comparison of the input impedance and reflection coefficient is presented.

The prototype of the proposed dual-band HRS bent slot antenna based on this design procedure was fabricated on an FR4 substrate. The measured frequency bands for a VSWR <2 are 2.40–2.49 GHz and 3.39–3.72 GHz, with measured gain ranges of 1.4–1.9 dBi and 2.0–2.9 dBi, respectively. In addition, the horizontal-direction slot length of the proposed antenna is reduced by 35%, compared to a conventional dual-band ACRSA.

The proposed antenna can be used as a compact dual-band antenna for WLAN and WiMAX applications.

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REFERENCES

[1] R. Waterhouse, *Printed Antennas for Wireless Communications*. Chichester, UK: Wiley, 2007.

[2] R. Krishan and H. Kim, "'X' shape slot based microstrip fractal antenna for IEEE 802.11 WLAN," *Asia-pacific Journal of Multimedia Services Convergent with Art, Humanities, and Sociology*, vol. 6, no. 8, pp. 529–537, 2016.

[3] R. Garg, P. Bhartia, and A. Ittipiboon, *Microstrip Antenna Design Handbook*. Boston, MA: Artech House, 2001.

[4] S. Y. Chen, Y. C. Chen, and P. Hsu, "CPW-fed aperture-coupled slot dipole antenna for tri-band operation," *IEEE Antennas and Wireless Propagation Letters*, vol. 7, pp. 535–537, 2008.

[5] K. L. Wong and L. C. Lee, "Multiband printed monopole slot antenna for WWAN operation in the laptop computer," *IEEE Transactions on Antennas and Propagation*, vol. 57, no. 2, pp. 324–330, 2009.

[6] Y. Cao, B. Yuan, and G. F. Wang, "A compact multiband open-ended slot antenna for mobile handsets," *IEEE Antennas and Wireless Propagation Letters*, vol. 10, pp. 911–914, 2011.

[7] Y. C. Lu and Y. C. Lin, "A mode-based design method for dual-band and self-diplexing antennas using double T-stubs loaded

aperture," *IEEE Transactions on Antennas and Propagation*, vol. 60, no. 12, pp. 5596–5603, 2012.

[8] M. J. Chiang, S. Wang, and C. C. Hsu, "Compact multifrequency slot antenna design incorporating embedded arc-strip," *IEEE Antennas and Wireless Propagation Letters*, vol. 11, pp. 834–837, 2012.

[9] T. H. Chang and J. F. Kiang, "Compact multi-band H-shaped slot antenna," *IEEE Transactions on Antennas and Propagation*, vol. 61, no. 8, pp. 4345–4349, 2013.

[10] D. Mitra, B. Ghosh, A. Sarkhel, and S. R. B. Chaudhuri, "A miniaturized ring slot antenna design with enhanced radiation characteristic," *IEEE Transactions on Antennas and Propagation*, vol. 64, no. 1, pp. 300–305, 2016.

[11] W. H. Tu, "Analysis and design of coplanar waveguide-fed capacitively coupled slot antennas," in *Proceedings of 2015 International Workshop on Antenna Technology (iWAT)*, Seoul, Korea, pp. 265–267, 2015.

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