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RESEARCH PAPER

Asymmetric coplanar inverted L-strip-fed monopole antenna with modified ground for dual band application

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A compact asymmetric coplanar strip (ACS)-fed monopole antenna for dual-band application is presented. The single-layer antenna composed of inverted L-shaped exciting strip and an L-shaped lateral ground plane. The antenna resonating at two different frequencies, 2.4 and 5.8 GHz is covering the wireless local area network/radio frequency identification bands. The antenna has an overall dimension of 35 × 5.7 mm² when printed on a substrate of dielectric constant 4.4 and loss tangent 0.02. The planar design, simple feeding, and compactness make it easy for the integration of the antenna into circuit boards. Details of the antenna design, and simulated and experimental results are presented and discussed. The experimental result shows good conformity with simulated results. The simulation tool based on the method of moments (Mentor Graphics IE3D version 15.10) has been used to analyze and optimize the antenna.

Keywords: Antennas and propagation for wireless systems, Antenna design, Modeling and measurements

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I. INTRODUCTION

The sudden growth of wireless internet for high data rate communication has fostered great attention toward the design of compact antennas. Different types of designs catering to various user requirements and multiband applications have been reported in the literature [1–19]. A small planar antenna with L-shaped shorted wire for triple-band application reported in [2]. A dual wide band G-shaped slotted antenna proposed in [3]. A triband U-shaped monopole antenna proposed for WiMAX and WLAN in [4]. The various slotted multiband antennas reported in [5–11]. These designs, however, have complex structures which make them difficult to integrate with WLAN systems. Planar antennas have the advantage of easy integration with active circuits. In this paper, we present asymmetric coplanar strip (ACS) inverted L-fed dual-band antenna with modified ground structure. The resulting antenna operates at two different bands in which 2.4 GHz used for WLAN and 5.8 GHz for WLAN/RFID application. The ground modification in the form of inverted L which reduces the ground dimensions much comparing with existing geometries. The exciting strip also in the form of inverted L, so overall dimension is about 35 × 5.7 mm².

In this paper, the prime focus on miniaturization of the proposed design comparing with existing variants. An inverted

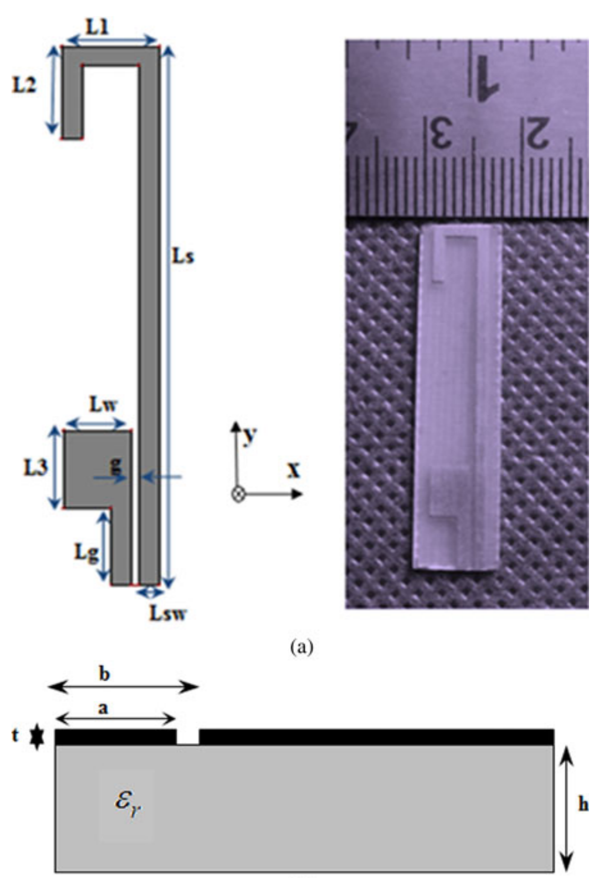

Fig. 1. (a) Geometry of proposed antenna and its prototype (b) side view.

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Table 1. Parameters of the proposed antenna.

Parameter	*Ls*	*Lg*	*Lw*	*L1*	*L2*	*L3*	*Lsw*	*g*
Value (mm)	35	5	4	5.7	6	5	1.2	0.5

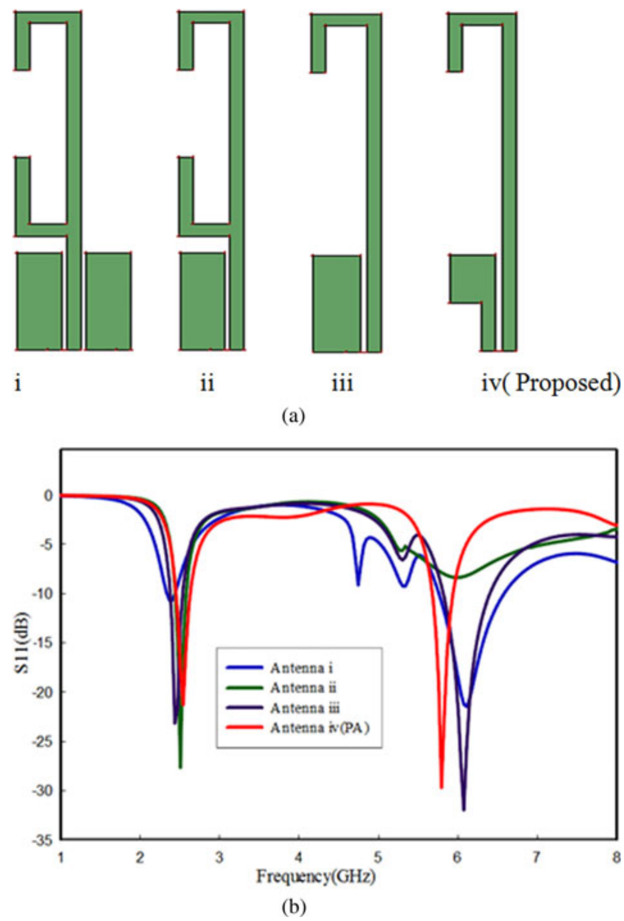

Fig. 2. (a) Design evolution of proposed antenna, (b) simulated return loss results.

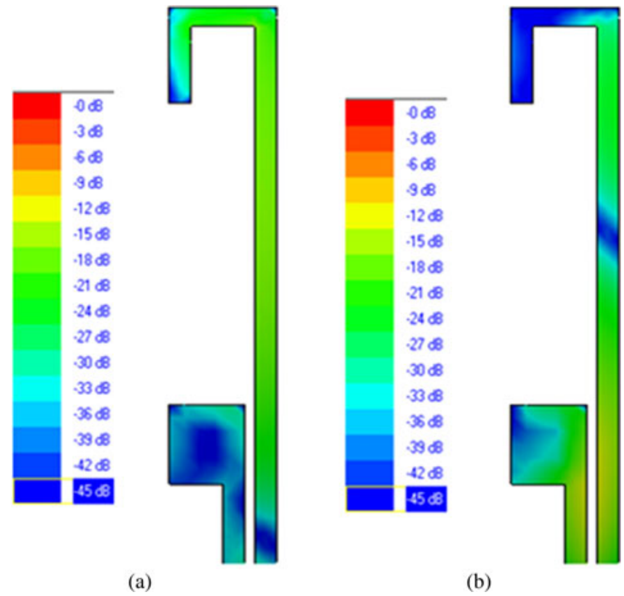

Fig. 4. Current distribution of proposed antenna (a) 2.4 GHz and (b) 5.8 GHz.

L and F ACS-fed geometry is proposed for WLAN in [12–14]. A similar kind of inverted L-fed geometry with multiple L branches for multi-band operation is proposed in [15]. However, those designs investigated in the recent literature have larger size than our current proposal. The feeding mechanism of an antenna is a crucial factor as far as the compactness is taken into account. Normally the feed structure consumes much of the overall dimension of the antenna. In this design, a compact and effective feeding technique is employed. The ACS feed used here has all the advantage of a uniplanar feed along with compactness. This feeding mechanism is analogous to the coplanar waveguide (CPW) feed structure except that the ACS feed has a single lateral ground plane compared to the twin lateral plane strips in the CPW feed structure. The overall size of the antenna reduced about half comparing with CPW-fed antenna.

II. PROPOSED ANTENNA CONFIGURATION

Figure 1 shows the geometry and prototype of the asymmetric coplanar inverted L-fed proposed antenna having length *Ls* and width *Lsw*. The feed of proposed antenna is designed using standard design equations of ACS [16, 20]. The ground plane dimensions of the antenna are optimized by

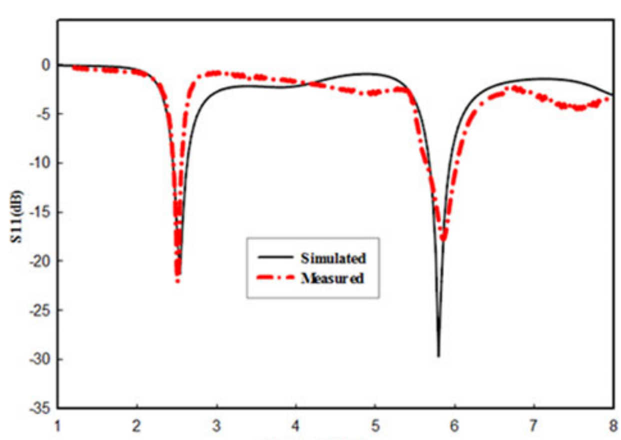

Fig. 3. Comparison between simulated and measured return loss.

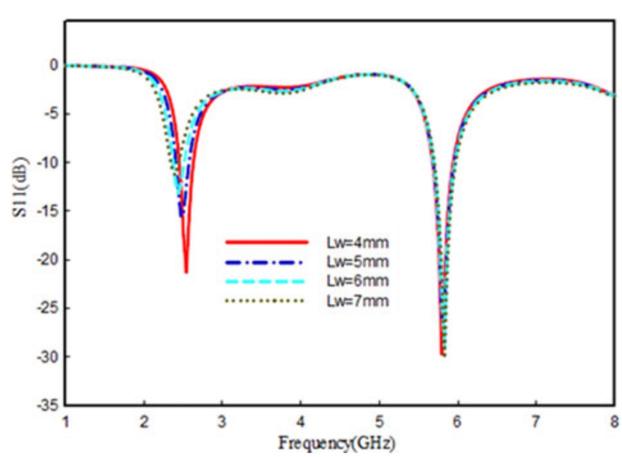

Fig. 5. Effect of ground plane width of the proposed antenna.

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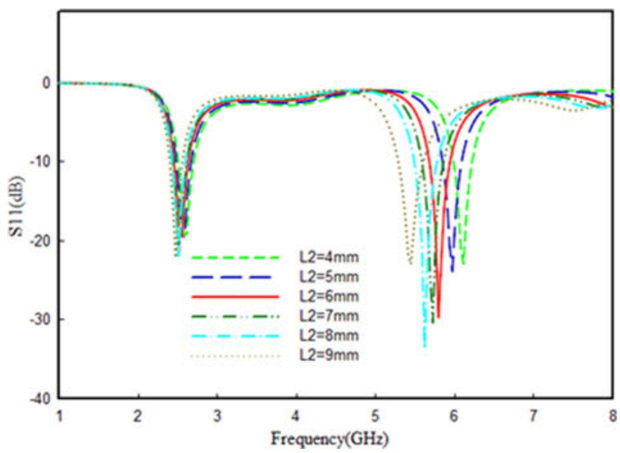

Fig. 6. Effect of variation on leg length ($L2$) of inverted L exciting strip.

iteration for good impedance matching. The antenna is designed and printed on an FR4 epoxy substrate having dielectric constant 4.4 and thickness 0.8 mm. It has to be noted that the overall antenna dimensions (Table 1) in terms of area is greatly reduced in the case of the proposed antenna using the ACS feed since it uses only a single lateral ground plane.

The percentage reduction of area is almost about 50% when compares with similar CPW-fed antennas because it is using single lateral ground plane comparing with twin lateral ground plane in the CPW. So ACS-fed antennas are the promising candidates for the future generation antennas.

Figure. 2 shows the design evolution of the proposed antenna. Initially started from a CPW-fed C-shaped strip-fed geometry and finally we arrived on the proposed ACS L-fed design with miniature size. Figure 2 shows the comparison of return loss characteristics of the proposed antenna with its possible variants. From Fig. 2 we can identify the changes and size reduction when the design development phase of the proposed antenna.

The design equations for the perfect matching of impedance are given below:

$$Z_o = \frac{60\pi}{\sqrt{\varepsilon_{eff}}} \frac{K(k)}{K(k^1)}, \tag{1}$$

where from Fig. 1(b)

$$k = \frac{a}{b},$$
$$k^1 = \sqrt{1 - k^2},$$

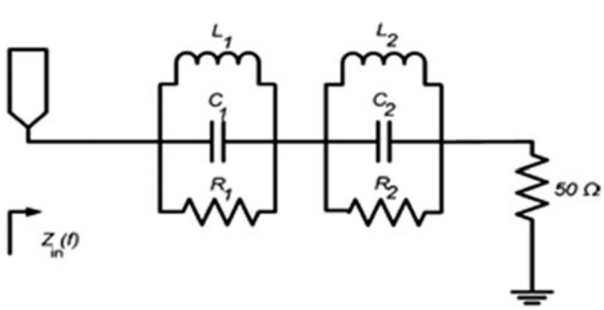

Fig. 7. Lumped RLC equivalent model of proposed antenna.

Table 2. Calculated values of equivalent circuit lumped elements.

Circuit/parameters	R (Ω)	L (nH)	C (pF)
1	47	0.51	7.60
2	53	0.325	2.48

and $K(k)/K(k^1)$ is the elliptical integral of first kind which is given by

$$\frac{K(k)}{K(k^1)} = \begin{cases} \dfrac{\pi}{\ln \dfrac{2(1+\sqrt{k^1})}{(1-\sqrt{k^1})}} & 0 \le k \le \dfrac{1}{\sqrt{2}}, \\[2ex] \dfrac{1}{\pi \ln \dfrac{2(1+\sqrt{k})}{(1-\sqrt{k})}} & \dfrac{1}{\sqrt{2}} \le k \le 1, \end{cases} \tag{2}$$

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2}. \tag{3}$$

III. RESULTS AND DISCUSSION

The simulated, parametric study and measured results of the proposed antenna have also been observed. The measured and simulated results of return loss characteristics for optimized set of antenna parameters are presented in Fig. 3. From the simulated results it is found that the proposed antenna yield dual-band resonance centered at 2.45 and 5.8 GHz which covers IEEE 802.11 WLAN bands 2.4 GHz (2.4–2.48 GHz) and 5.8 GHz (5.725–5.825 GHz) which is useful for RFID applications. The proposed antenna fabricated on an FR4 substrate by simple chemical etching and screen-printing process. The measurement is carried out using HP8510C vector network analyzer. The measured results show good agreement of dual-band operation of the proposed antenna which ranges 2.42–2.5 GHz in lower frequency band and 5.7–5.95 GHz in upper frequency band.

The simulated current distribution of the proposed antenna shown in Fig. 4, which shows the current perturbation of the proposed design is more in the ground plane for lower band of resonance and in upper band of resonance

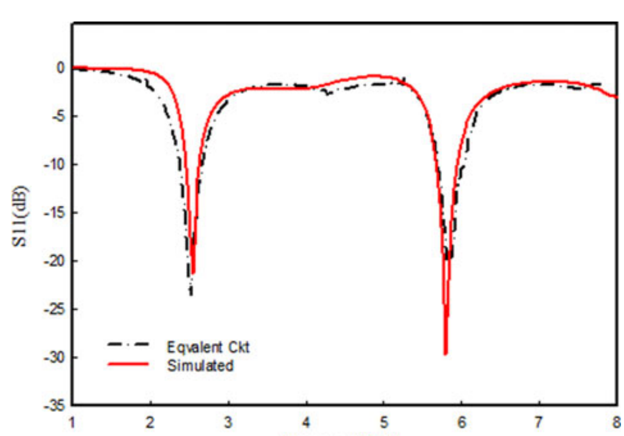

Fig. 8. Comparison between simulated and lumped equivalent model.

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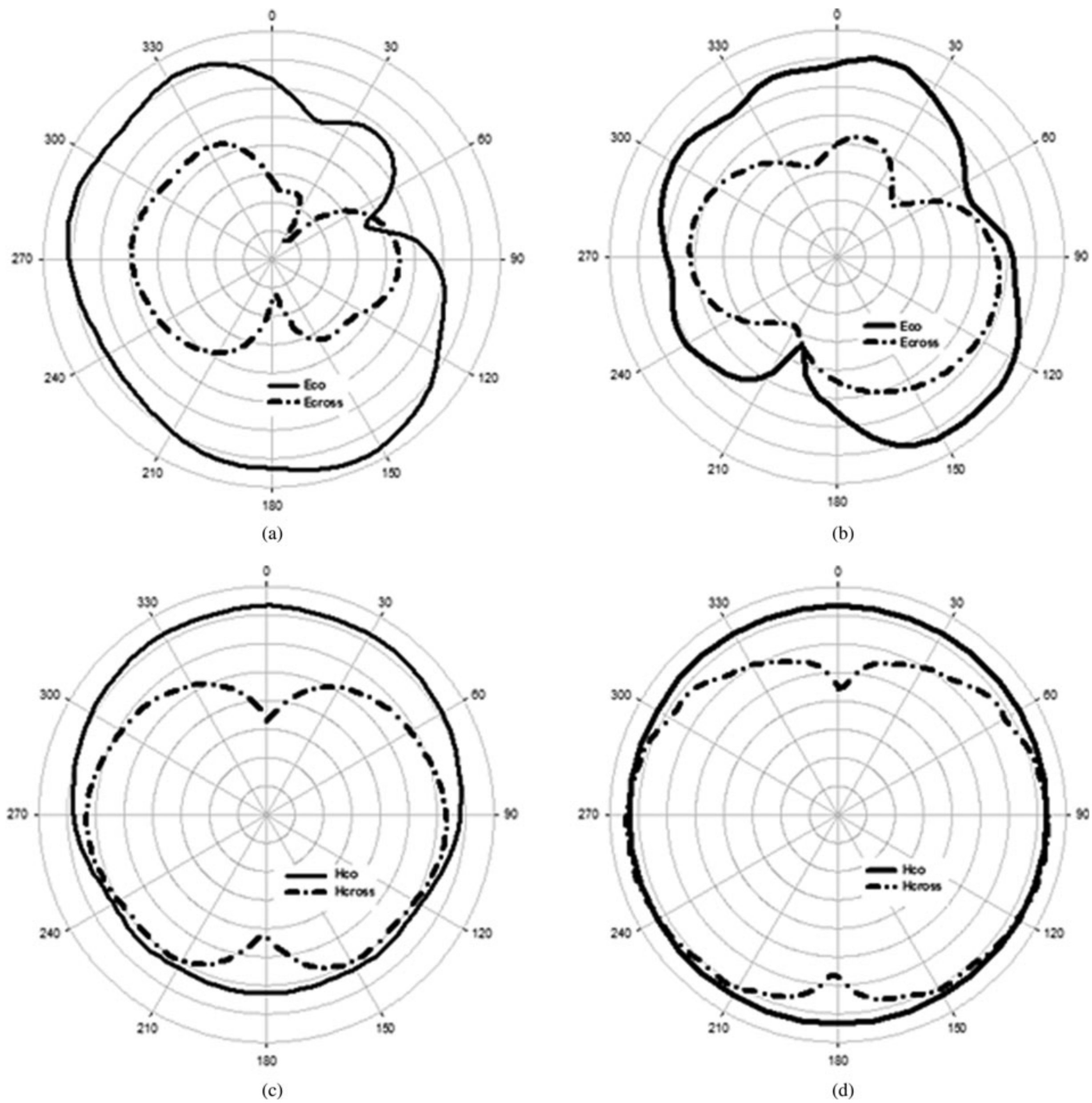

Fig. 9. Measured radiation patterns of the proposed antenna (a) *E*-plane at 2.4 GHz, (b) *E*-plane at 5.8 GHz, (c) *H*-plane at 2.4 GHz, and (d) *H*-plane at 5.8 GHz.

current through exciting strip is prompting. The parametric analysis of the proposed antenna by varying width of the ground plane *Lw* and leg length of exciting strip *L*1 are shown in Figs. 5 and 6, respectively. The ground width has great influence on the lower frequency band 2.4 GHz. Here it is found that when the width of ground plane increases the lower resonance tends to shift and goes on decreasing. The optimum results obtained on the $Lw = 4$ mm. The parametric study on changing the value of leg of exciting strip *L*2 also carried out. It is clear that *L*2 has an effect on upper resonance and optimum performance obtained when $L2 = 6$ mm. So the parameters can be used for tuning the proposed antenna in different nearby applications.

Table 3. Comparison between size and gain of proposed and existing literatures.

Published literatures (Ref)	Peak gain (dBi)	Purpose of antenna	Size comparison total area (mm²)
Proposed	3.4	WLAN	35 × 5.7
[12]	1.21	WLAN	37.5 × 24
[13]	2.1	WLAN	30 × 28
[14]	1.9	WLAN	21 × 19
[15]	2.5	WLAN	26.5 × 12
[16]	1.25	WLAN	17 × 12
[17]	3.5	WLAN	35 × 15
[18]	3.3	WLAN	28 × 12.5

The simple RLC series lumped equivalent model for the proposed antenna for the dual band of resonance shown in Fig. 7. The basic circuit parameters are obtained from designed equations and simulated by mentor Graphics IE3D modua. This analysis carried out by large number of iterations and data fitting, finally obtained an optimized circuit parameters shown in Table 2. For obtaining the equivalent circuit extracts *R* and *L* values from IE3D modua for each

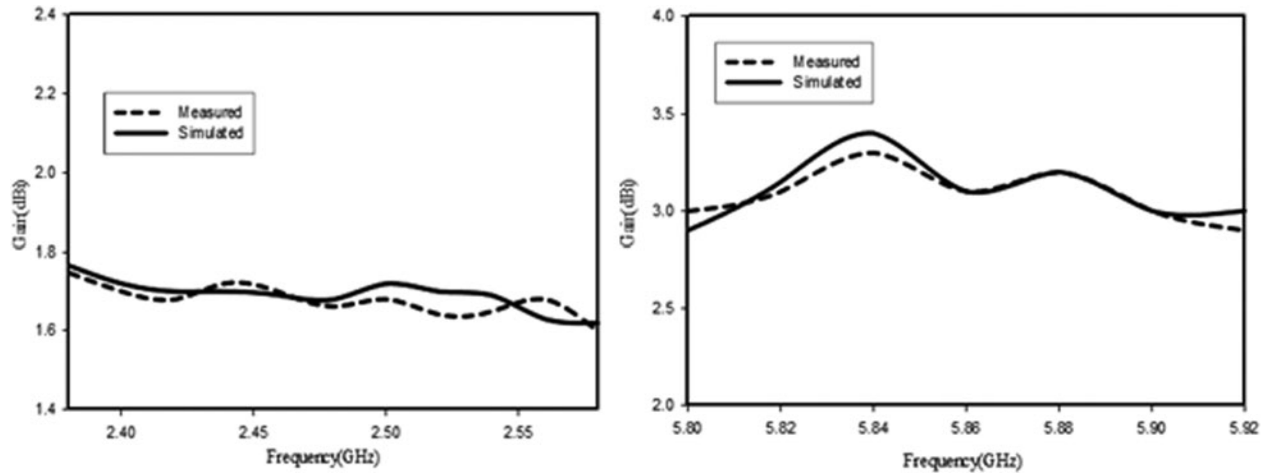

Fig. 10. Measured and simulated gain of the proposed antenna at lower frequency band and upper frequency band.

resonance and cascaded to form the complete equivalent circuit. The comparison between the simulated and lumped equivalent modal of the proposed antenna shown in Fig. 8, which shows good conformity between both results

$$C = \frac{5f_c}{\pi\left(f_c^2 - f_p^2\right)}\,\mathrm{pF}, \quad (4)$$

$$L = \frac{250}{C\left(\pi f_p^2\right)}\,nH, \quad (5)$$

$$R = \frac{2Z_0}{\sqrt{\frac{1}{S_{11}(f)^2} - (2Z_0(fC - \frac{1}{wL}))^2 - 1}}\,\Omega s. \quad (6)$$

The measured radiation patterns of the *E*- and *H*-planes for 2.4 and 5.8 GHz are given in Fig. 9. The results show good and omnidirectional radiation pattern at the *H*-plane and bidirectional patterns at the *E*-plane. The small asymmetry in the patterns is because of asymmetry in the proposed antenna feeding configuration. The polarization of the antenna is also experimentally determined and it is found that antenna is polarized along the *X*-axis for dual band of operation. The cross-polarization level of the proposed antenna is minimum comparing with co-polarization levels.

The comparison between area and gain of the proposed antenna with some of the published literatures is shown in Table 3. Here it is observed that the proposed structure has prevailing profile reduction comparing with the existing ACS-fed multiband WLAN antennas. The gain characteristics also shows good agreement with existing geometries. The proposed designs yield peak gain of 1.6 dBi at lower band and 3.4 dBi at upper band of resonance, which is shown in Fig. 10.

IV. CONCLUSION

In this paper, a novel compact ACS-fed dual-band monopole antenna for WLAN/RFID applications is presented. The proposed antenna has compact size (35 × 5.7 mm^2) and moderate gain for multiband performance. Its simple geometry, compact size, symmetrical radiation pattern, and good electrical performance make the proposed geometry effective for use in wireless gadgets. Therefore, the proposed antenna is the useful candidate for WLAN applications.

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REFERENCES

[1] Chen, Z.N.: Antennas for Portable Devices, Wiley, England, 2007, 1–52.

[2] Jan, J.-Y.; Tseng, L.-C.: Small planar monopole antenna with a shorted parasitic inverted-L wire for wireless communications in the 2.4–5.2, and 5.8-GHz bands. IEEE Trans Antennas Propag., **29** (2004), 1903–1905.

[3] Kang, L.; Yin, Y.-Z.; Li, H.; Huang, W.-J.; Zheng, S.-F.: Dual wide band symmetrical G-shaped slotted monopole antenna for WLAN/WiMAX application. Prog. Electromagn. Res. Lett., **17** (2010), 55–65.

[4] Li, B.; Yan, Z.; Zhang, T.: Triple band Slot Antenna with U shaped open stub fed by asymmetric coplanar strip for WLAN/WIMAX applications. Prog. Electromagn. Res. Lett., **37** (2013), 123–131.

[5] Song, Y.; Jiao, Y.C.: Compact slot antenna fed by asymmetric coplanar strip for 2.4/5 GHz WLAN operations. Microw. Opt. Technol. Lett., **50** (2008), 3080–3083.

[6] Lee, Y.-C.; Sun, J.-S.: A new printed antenna for multiband wireless applications. IEEE Antennas Wirel. Propag. Lett., **8** (2009), 402–405.

[7] Thomas, K.-G.; Sreenivasan, M.: Compact triple band antenna for WLAN/WiMAX applications. Electron. Lett., **45** (2009), 811–813.

[8] Dang, L.; Lei, Z.-Y.; Xie, Y.-J.; Ning, G.-L.; Fan, J.: A compact micro strip slot triple-band antenna for WLAN/WiMAX applications. IEEE Antennas Wirel. Propag. Lett., **9** (2010), 1178–1181.

[9] Hu, W.; Yin, Y.-Z.; Fei, P.; Yang, X.: Compact tri band square-slot antenna with symmetrical L-strips for WLAN/WiMAX applications. IEEE Antennas Wirel. Propag. Lett., **10** (2011), 462–465.

[10] Ren, X.-S.; Yin, Y.-Z.; Hu, W.; Wei, Y.-Q.: Compact tri-band rectangular ring patch antenna with asymmetrical strips for WLAN/WiMAX applications. J. Electromagn. Waves Appl., **13** (2010), 1829–1838.

[11] Lai, C.-P.; Chiu, S.-C.; Chen, S.-Y.: Miniaturization of CPW-fed slot antennas using reactive terminations and truncated bilateral ground plane. IEEE Antennas Wirel. Propag. Lett., **11** (2012), 1072–1075.

[12] Askarali, P.; Sreenath, S.; Sujith, R.; Dinesh, R.; Krishna, D.D.; Anandan, C.K.: A compact asymmetric coplanar strip fed dual band antenna for DCS/WLAN application. Microw. Opt. Technol. Lett., **54** (2012), 1087–1089.

[13] Deepu, V.; Raj, R.-K.; Joseph, M.; Suma, M.-N.; Monahan, P.: Compact asymmetric coplanar strip fed monopole antenna for multiband applications. IEEE Trans. Antennas Propag., **55** (2007), 2351–2357.

[14] Deepu, V.; Sujith, R.; Mridula, S.; Aanandan, C.-K.; Vasudevan, K.; Monahan, P.: ACS fed printed F-shaped uniplanar antenna for dual band WLAN applications. Microw. Opt. Technol. Lett., **51** (2009), 1852–1856.

[15] Liu, Y.F.; Wang, P.; Qin, H.: A compact tri band ACS fed monopole antenna employing inverted L-branches for WiMAX and WLAN application. Prog. Electromagn. Res. C, **47**, (2014), 131–138.

[16] Simons, R.N.: Coplanar Waveguide Circuits, Components an Systems, John Wiley & Sons, New York, NY, 2004.

[17] Li, Y.; Li, W.; Mittra, R.: Miniaturization of ACS-fed dual band antenna with loaded capacitance termination. IEICE Electron. Express, **10** (2013), 1–8.

[18] Sim, C.-Y.-D.: Dual band CPW fed monopole antenna with asymmetrical ground plane for bandwidth enhancement. Microw. Opt. Technol. Lett., **50** (2008), 3001–3004.

[19] Li, Y.; Li, W.; Yi, Q.: Miniaturization of asymmetric coplanar strip fed staircase ultra wide band antenna with reconfigurable notch band. Microw. Opt. Technol. Lett., **55** (2013), 1467–1470.

[20] Garg, R.; Bhartia, P.; Bahl, I.: Micro Strip Antenna Design Hand Book, Artech House, MA, 2001.

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