A Dual-Band Circularly Polarized Monopole Antenna for WLAN Application

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***Abstract*— A novel design of monopole antenna with trapezoidal configuration is presented for WLAN application. The proposed antenna provides dual-band circularly polarized at 2.4 and 5.3 GHz frequencies with 6.25% and 2.83% bandwidth, respectively. The antenna is fed through a microstrip feed line and is backed by a finite ground plane with two tuning stubs. The circular polarization for the proposed dual-band antenna is demonstrated by 3dB axial ratio (AR) spectrum. Simulation results are provided by using two full wave software packages, Ansoft HFSS and CST microwave studio and the results are compared with each other.**

I. INTRODUCTION

The rapid development of wireless communications urges the need of UWB, dual-band or multiband antennas. Circularly Polarized (CP) printed antennas are widely used in many wireless communication systems such as radio frequency identification (RFID), global positioning systems (GPS), satellite communication systems, dedicated short range communication systems (DSRC), navigation, WiMAX and WLAN [1]-[5]. These types of antennas are very attractive, because of their low profile, light weight and ease of fabrication characteristics.

Generally, the radiation patterns of the printed monopole antennas are linearly polarized (LP); they are difficult to radiate circularly polarized (CP) radiation wave which are generated by two near-degenerated orthogonal resonant modes of equal amplitude and 90 phase difference (PD). Recently many studies on printed monopole antennas with a single feed structure have been reported. To produce single frequency band of operation, [1] has introduced a fractal boundary microstrip antenna resulting in 1.6% of 3 dB axial ratio (AR) bandwidth and [2] has used an annular-ring slot with double-bent microstrip line feed giving 10% 3 dB AR bandwidth. To produce a dual band CP, [3] has employed a combination of slit, beveling and stub either on the monopole antenna or on the ground plane resulting in 2.41-2.56 GHz and 3.31-3.54 GHz bands. Also CPW fed slot antenna loaded with two spiral slots has been reported in [4], resulting in 8.4% and 19.24% bandwidth with respect to 1.6 GHz (RHCP) and 2.2 GHz (LHCP) centre frequencies, respectively.

In this paper we present a novel small sized trapezoidal-shaped monopole antenna that can provide dual-band CP

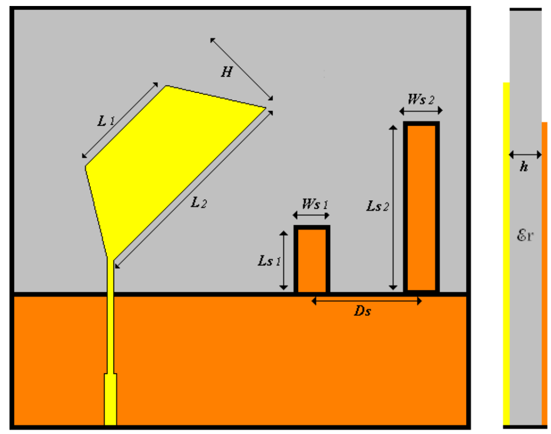

Fig.1. The structure of the single feed trapezoidal-shaped printed monopole antenna with stubs

radiation for WLAN application. The proposed antenna supports 6.25% CP bandwidth at 2.4 GHz for the lower band and 2.83% CP bandwidth at 5.3 GHz for the upper band. The gain of the proposed antenna is about 2dB at the lower band and about 0.1 dB at the upper band which is almost a proper gain for such types of antennas. Also by adjusting the parameters of the antenna the centre frequency of both bands can be tuned easily in order to support other applications. Two full wave software packages, Ansoft HFSS based on finite element method and CST microwave studio, based on finite integration technique, are used to simulate the proposed antenna. Simulation results are provided and results are discussed.

II. ANTENNA DESIGN

The proposed antenna consists of four parts. Trapezoidal radiator, microstrip feed line, ground plane and tuning stubs. Geometry of the antenna is depicted in Fig.1. To have dual band operation a trapezoidal-shaped monopole antenna is employed. The design of the trapezoid can be carried out based on the given lower and upper frequency bands. Based on these two frequencies, through the following formula appropriate values for the two side lengths L_1 and L_2 can be obtained:

$$f_r = \frac{c}{2\sqrt{\varepsilon_{eff}}\,L} \quad (1)$$

Where ε_{eff} is given by:

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} \quad (2)$$

The height of the trapezoidal patch, H, is chosen based on the required gain and good radiation patterns in the desired frequency bands. It is apparent that a bigger H would results in higher gain.

The microstrip feed line dimensions are calculated to achieve good impedance matching and minimum return loss.

Tuning stubs are used to perform the 3 dB AR. As shown in [3], stub in the ground plane can further increase the impedance-bandwidth and AR-bandwidth. The lengths Ls_1 and Ls_2 and the spacing Ds between the two stubs affect the centre frequency of the two bands. Ls_1 and L_1 are in direct relation with upper CP band; and lower CP band is influenced by Ls_2 and L_2 directly. It should be noticed that the dimensions of the stubs are obtained through optimization that results in 3 dB AR and return loss of higher than 10 dB. The dimensions of the antenna obtained are: L_1 = 41 mm, L_2 = 64 mm, Ls_1 = 14.3 mm, Ls_2 = 49.6 mm, Ws_1 = 8.52 mm, Ws_2 = 8.52 mm, Ds = 31.3 mm, H = 20 mm. The FR4 substrate with 1.6 mm thickness and ε_r = 4.4 is used.

III. SIMULATION RESULTS

The simulated return loss of the antenna is shown in Fig. 2. It is observed that the antenna shows dual-band impedance bandwidth behaviour. The antenna resonances are in the desired bands.

To investigate the operation of the resonant mode, surface current distribution is simulated and presented in Fig. 3 at centre frequencies of the two bands. As mentioned in the previous section, the longer stub is responsible for providing 3 dB AR for the lower band and the short stub for the higher band. From Fig. 3 it is obvious that the maximum surface current is localized in the longer stub and on the larger side of the trapezoid yielding a resonant mode at 2.4 GHz and similarly strong current on the shorter stub and along the smaller side of the trapezoidal patch results in a resonance at 5.3 GHz. By tuning the space between the two stubs and their lengths the required 90º phase shift is provided.

To attain CP radiation we need to obtain the AR and PD performance. The AR diagrams for the lower and upper bands are shown in Fig. 4. As can be seen the 3 dB AR bandwidth is obvious in both dual-band frequencies. The proposed antenna supports 6.25% CP bandwidth at 2.4 GHz for the lower band and 2.83% CP bandwidth at 5.3 GHz for the upper band. Excellent agreement between the HFSS and CST results verifies the performance of the designed structure.

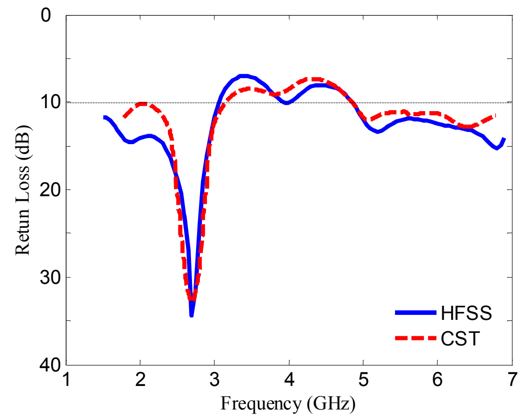

Fig. 2 Return Loss of the proposed Trapezoidal- shaped monopole antenna

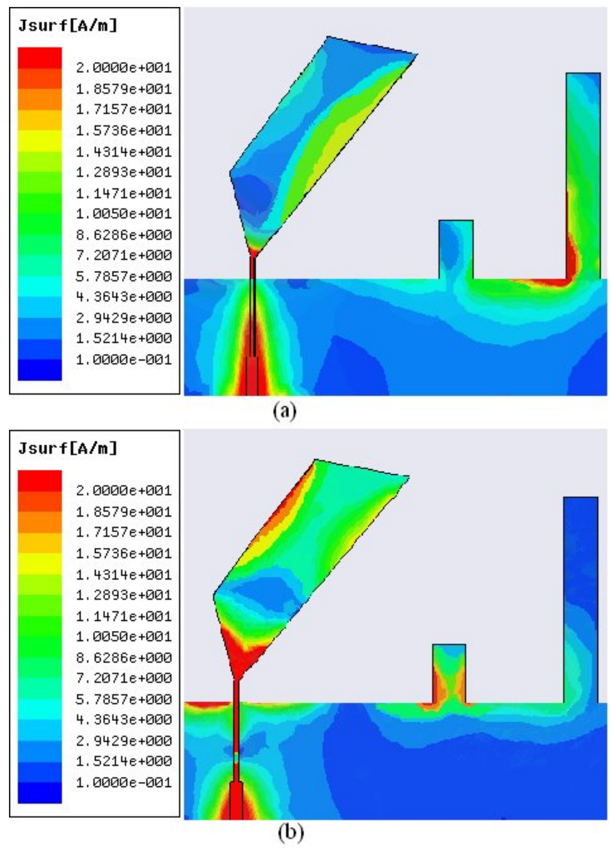

Fig. 3 Simulated surface current distribution resonant mode at centre frequencies of lower and upper bands (a) 2.4 GHz, (b) 5.3 GHz.

The PD diagram of the structure as a function of frequency is depicted in Fig. 5.The PD variation in both the lower and upper bands is close to 90º to generate circular polarization. These results are obtained at the broadside direction.

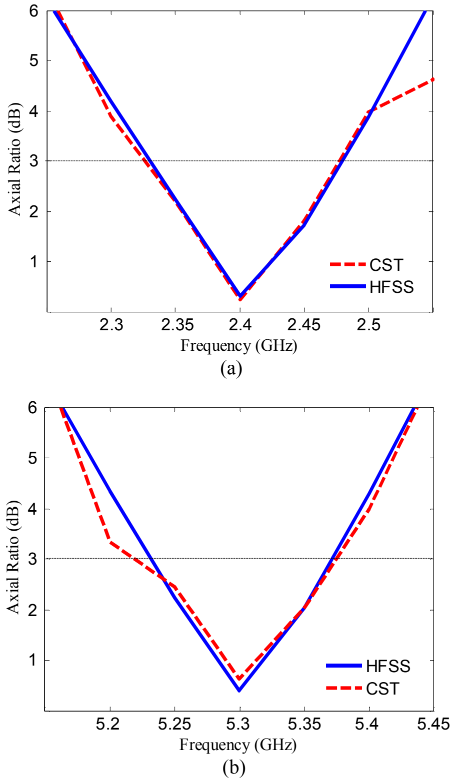

Fig. 4 Axial Ratio of the proposed dual band CP antenna at: (a) 2.4 GHz and (b) 5.3 GHz.

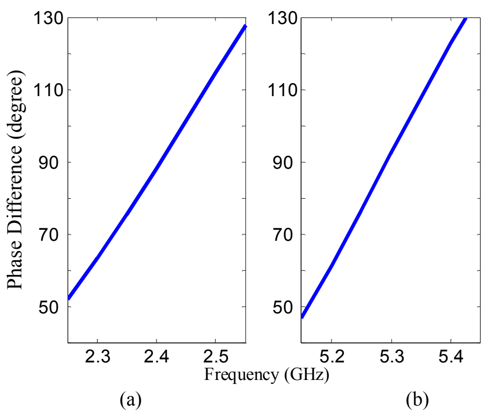

Fig. 5 Phase Difference diagrams of the proposed antenna (a) 2.4 GHz, (b) 5.3 GHz.

Fig. 6 shows the RHCP and LHCP radiation patterns for both the lower and upper bands of the proposed antenna. It should be noted that the radiation patterns are not omnidirectional because the structure of the proposed antennas is not symmetric and the radiation patterns are influenced by the stubs. We observe that good LHCP and RHCP radiation patterns are excited in both of the lower and upper bands. The performance of the antenna is concluded in Table I.

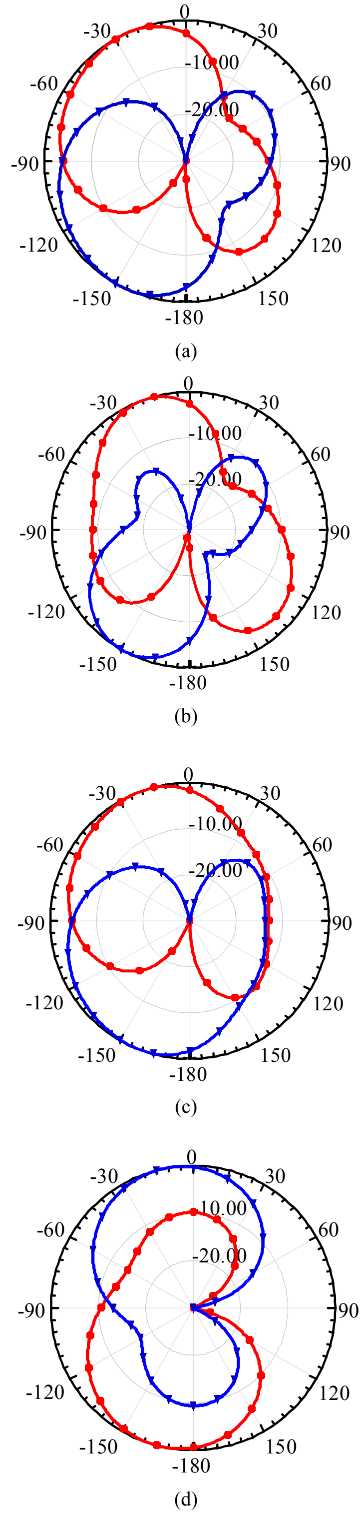

Fig. 6 Simulated (▲ RHCP) and (● LHCP) radiation patterns of the proposed antenna at: (a) XZ- plane 2.4 GHz, (b) YZ- plane 2.4GHz, (c) XZ-plane 5.3 GHz, and (d) YZ- plane 5.3 GHz.

TABLE I
TRAPEZOIDAL-SHAPE MONOPOLE ANTENNA PERFORMANCE

Band	Center Frequency (GHz)	Gain (dB)	Axial Ratio (dB)	Bandwidth |GHz (%)| AR< 3	VSWR	(PD) (degree)
Lower	2.4	2	0.308	6.25	1.49	88.9
Upper	5.3	0.1	0.834	2.83	1.8	91.2

IV. CONCLUSION

A single feed printed monopole antenna with dual-band CP radiation has been presented. Two full wave simulation software packages, HFSS and CST have been used to verify the simulation results of the designed antenna. Monitoring of the AR diagrams has shown that the proposed antenna provides 6.25% CP bandwidth at 2.4 GHz for the lower band and 2.83% CP bandwidth at 5.3 GHz for the upper band. Also antenna gain is 2dB and 0.1dB in lower and upper band, respectively. By varying the antenna parameters such as the patch side lengths, stubs lengths and widths and their spacing the CP center frequency of each of the bands can be adjusted for use in other applications.

REFERENCES

[1] P. Nageswara Rao and N.V.S.N. Sarma, "Fractal boundary circularly polarised single feed microstrip antenna," *Electron. Lett*., vol. 44 no. 12, pp.713 - 714, June 2008.

[2] Jia-Yi Sze, Chung-t-I. G. Hsu, Min-Hua Ho, Yu-He Ou, and Ming-Ting Wu, "Design of Circularly Polarized Annular-Ring Slot Antennas Fed by a Double-Bent Microstripline," *IEEE Trans. on Antennas Propag.,* vol. 55, no. 11, pp. 3134 - 3139 , Nov. 2007.

[3] Christina F.jou, Jin Wei Wu, and Chien-Jen Wang, "Novel Broadband Monopole Antennas With Dual-and Circular Polarization," *IEEE Trans. Antennas Propag.*,vol.57, no.4, pp. 1027 - 1034, April 2009.

[4] Canhui Chen and E. K. N. Yung, "Dual-Band Dual-Sense Circularly Polarized CPW-Fed Slot Antenna With Two Spiral Slots Loaded," *IEEE Trans. Antennas Propag.,*vol. 57, no. 6, pp. 1829-1833 , June 2009.

[5] Nasimuddin, Z.N. Chen, and X. Qing, "Dual-Band Circularly Polarized -Shaped Slotted Patch Antenna With a Small Frequency-Ratio," *IEEE Trans. Antennas Propag.,*vol.58, no. 6, pp. 2112 - 2115, June 2010.