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Design of an Ultrawideband CPW-Fed Monopole Antenna with a Band-Notch Function

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***Abstract*—In this paper, a CPW-fed monopole antenna for ultra wideband (UWB) applications using band-notch characteristics with size of (24×24×1.6 mm^3) is presented. The antenna is designed for operation across the entire UWB from 3.1 to 10.6 GHz with band-notch in 5-6 GHz, by inserting an H-shaped slot on the CPW staircase feed line. The proposed antenna has a reflection coefficient below -10 dB through the frequency band. Also, reasonable gain values and good radiation pattern over the same frequency band have been observed. Details of the proposed antenna and experimental results are discussed and parametric study is presented.**

***Keywords*—Monopole antenna, notch-band, coplanar waveguide (CPW), UWB.**

I. Introduction

ACCORDING to high demand of the high data transmitting rate, low power consumption and small size, ultra-wideband (UWB) antennas have received great attention for wireless communication applications [1]. With regards to the FCC regulations, the frequency band from 3.1 to 10.6 GHz can be used for high speed wireless communication system [2]. A coplanar waveguide (CPW)-fed antenna has been reported for ultra-wideband operations [3]. A coplanar waveguide (CPW) monopole antenna becomes popular due to wide operation bandwidth, good radiation pattern, simple structure, light weight and ease of fabrication [4].

In [5], a CPW-fed rectangular slot antenna with a wide bandwidth of 98% over a 6 dB average gain was presented. Another CPW-fed monopole antenna was presented in [6] with tapered ground plane which is suitable for UWB applications. A novel printed monopole antenna fed by a CPW with frequency bandwidth from 3 to 11.3 GHz was obtained in [3]. And in [7] new compact CPW-fed rectangular antenna with a patched inverted-L stub was introduced.

As a matter of fact UWB transmitters should not cause any electromagnetic interference to nearby communication system such as the wireless local area network (WLAN) applications, for this reason we should pay attention to this concept for avoiding interfering with nearby communication systems such as IEEE 802.11a in the U.S. (5.15-5.35 GHz, 5.725-5.825 GHz) and HIPERLAN/2 in Europe (5.15-5.35 GHz, 5.47-5.725 GHz). Therefore UWB antennas with band-notched characteristics in the WLAN frequency band are required.

Some papers have studied effect of coupling between the feed line and the aperture by using different shape of slots (i.e., circular, elliptical, hat-shaped arc-shaped slot) on the feed line [8]–[13]. In [14] a corner-notched rectangular patch which is loaded by a square back-patch was presented. When it comes to CPW-Fed UWB antennas, most of the notched band characteristics are implemented by cutting slots in the radiation element.

In this paper, a novel UWB CPW-fed monopole antenna with a band-notch function in 5-6.1 GHz and compact size of 24(L)×24(W)×1.6 mm^3 is presented for UWB application which covers frequency bandwidth of 3.1-11.6 GHz. The proposed antenna has a reasonable average gain and good radiation pattern. Details of antenna design, simulated and measured results are presented and discussed.

Section II presents the geometry of the proposed antenna. Then in section III the effect on the impedance bandwidth, full band and band-notched function design are analyzed. After that the experimental results including measured return losses and radiation patterns are presented in section IV. Section V gives the conclusions.

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II. Antenna Configuration

The proposed UWB CPW-fed monopole antenna with a band-notch function is shown in Fig. 1. The antenna is printed on FR4 substrate with thickness of 1mm and relative permittivity of 4.4 and loss tangent 0.02. The proposed antenna consists of a square substrate which a square slot is etched at the center of the ground plane.

A CPW-fed line is a staircase strip and two gaps of width g which are located between the ground plane and a CPW-fed line. The gaps between the strips and ground plane are adjusted to reach reasonable impedance matching.

In proposed CPW-fed monopole antenna, two grounded semi-triangles metallic strips placed at down corners of the square slot and two circular metallic strips placed at up corners of the square slot which is modified ground plane to achieve a wide bandwidth.

Each of the semi-triangle metallic strips has a length of T_1 and T_2 in outside and a length of T_3 and T_4 in inside and each of circular metallic strips has a radious of A with center position of P_1 and P_2, H-shape slot has a width of W_6, W_7 and length of L_6, L_7, L_8. The antenna is excited by the 50Ω CPW feed line, which was in turn connected to a coaxial cable through a standard 50Ω SMA connector which is for measurement purpose. The lengths of sides of semi-triangles and center position of circular metalic strips are optimized by using a HFSS EM simulator from ANSOFT.

As well by varying the size of the monopole and two symmetry circular strips on the ground plane, the wideband

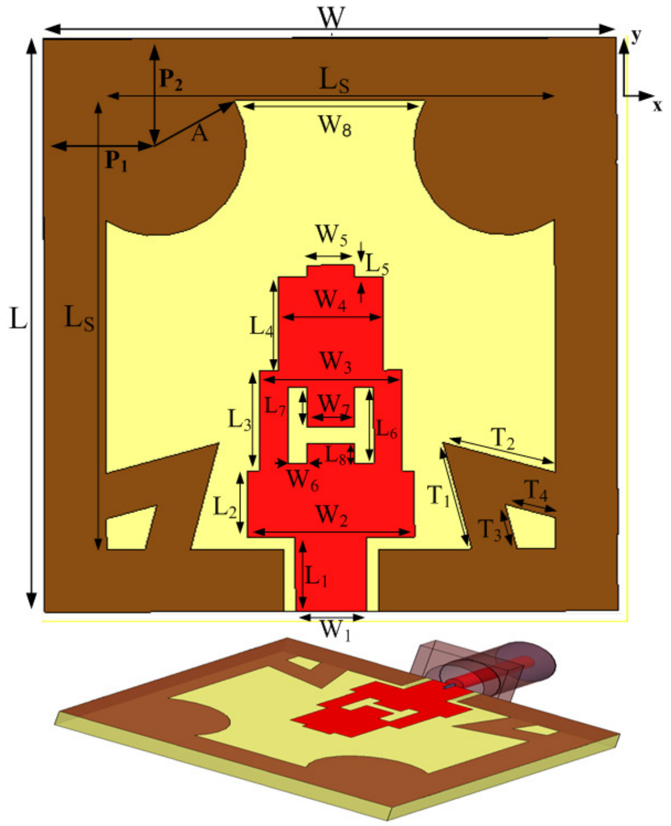

Fig. 1. Geometry of CPW-fed monopole antenna.

operation of the proposed antenna can be excited with a good impedance matching. By cutting the H-shaped slot on the radiating patch an additional surface current path along the slot is created which leads to the band notch characteristic.

The CPW feed line has a staircase shape with widths of W_1, W_2, W_3, W_4, W_5 which are respectively 3, 7, 6 , 4.4, 2, 0.8, 2 (units are in mm), and lengths of L_1, L_2, L_3, L_4, L_5 which are respectively 2.6, 2.8, 4.2, 3.9, 0.5(units are in mm). The inner of values of square slot with dimensions of $L_s \times L_s$ are 18.8×18.8 mm^2.

In proposed CPW-fed monopole antenna, the lengths of each semi-triangles, T_1, T_2, T_3 and T_4 are 4.6 mm, 4.9 mm, 1.93 mm and 2.18 mm respectively, A=3.7 mm and gap distance is g=0.5 mm. The H-shaped slot has width of W_6=0.8 mm, W_7=2 mm, and lengths of L_6=3.2 mm, L_7=1.67 mm and L_8=0.85 mm. The prototype of the antenna is shown in Fig. 1. with

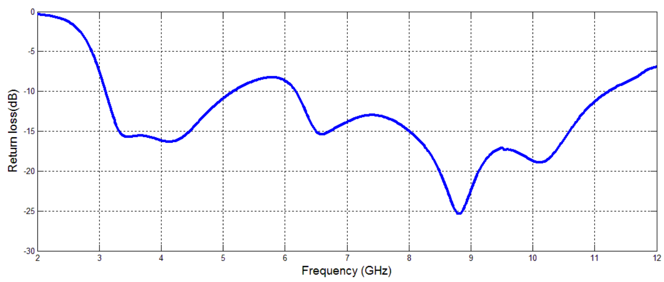

Fig. 2. Simulated reflection coefficient of the proposed antenna.

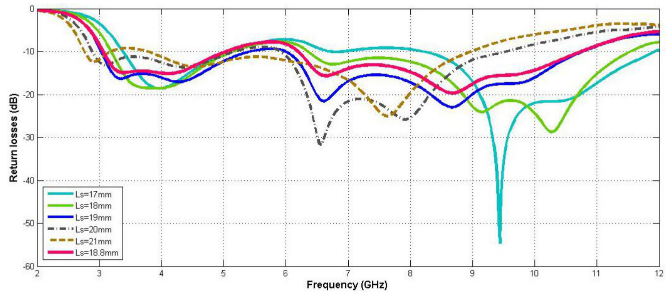

Fig. 3. Simulated reflection coefficients of the proposed antenna with different L_s with a fixed values of P_2=4.5 and T_2=4.87 (Units are in mm).

L_s=18.8 mm, P_1=4.4 mm, P_2=4.8 mm, A=3.7 mm, T_2=4.76 mm has been fabricated and tested.

III. Antenna Structure Studies

In this section, the monopole antenna with various design parameters is constructed. It is clearly seen that the monopole antenna exhibits a broad impedance bandwidth of 8 GHz (3-11 GHz). However, by inserting an H-slot on the staircase feed line one notched band at 5.5 GHz is obtained.

The simulated return loss of the (24×24 mm^2) CPW-fed monopole antenna with a band notch function is shown in Fig. 2. The result shows that the area of proposed antenna is reduced by 19.6% in comparison with [7], which is 32.4×24 mm^2. According to simulation result, the proposed antenna is covered impedance bandwidth of 3.1-5 GHz and 6.1-10.6 GHz for a return loss less than 10 dB.

Simulated reflection coefficients of the proposed antenna with different length of L_s are shown in Fig. 3. The results show that by increasing the length of L_s from 17 mm to 21 mm a lower frequency and upper frequency of bandwidth shift downward.

It shows that by increasing the length of L_s, the size and the area of ground plane will be decreased, consequently lower and upper edge from impedance bandwidth will decrease and by increasing the size of ground plane, impedance bandwidth will increase. The bandwidth is optimized at L_s=18.8 mm.

Similarly, the notch frequency can be obtained by changing the value of P_2 (center of circular grounded strip) on the corner of ground plane from P_2=3.8 mm to 5 mm with a fixed value of P_1=4.4 mm. As shown in Fig. 4, increase the return loss is observed at notched frequency by increasing P_2. By changing

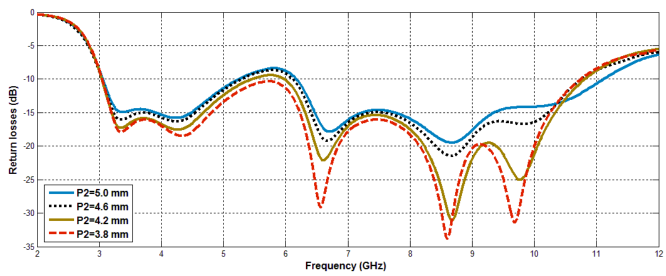

Fig. 4. Simulated reflection coefficients of the proposed antenna with different value of P_2 with a fixed values of P_1=4.4, L=18.8 and T_2=4.8 (Units are in mm).

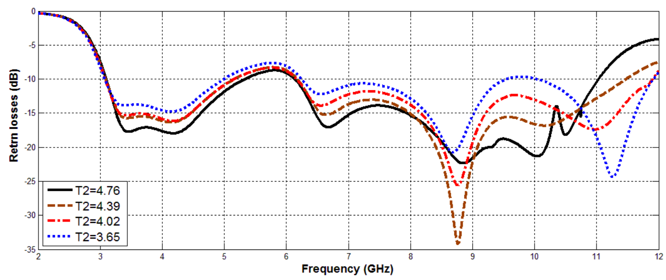

Fig. 5. Simulated reflection coefficients of the proposed antenna with different size of T_2 with a fixed values of P_1=4.4, P_2=4.5 and L_s=18.8 (Units are in mm).

the position of circular grounded strip the area of ground plane changed from 298 mm^2 to 310 mm^2.

Additionally simulated reflection coefficients in different side of triangle metallic strips from T_2=3.65 mm to 4.76 mm, is shown in fig. 5. It can be seen that notched frequency and lower frequency of bandwidth is almost fixed.

The edge of upper frequency of bandwidth decreased from 12 GHz to 11 GHz as T_2 increased from 3.65 mm to 4.76 mm. In this case the area of the ground plane is changed from 293 mm^2 to 303 mm^2.

The gap between radiation patch and ground plane has an important effect on the impedance matching of the proposed antenna, as shown in Fig. 6. When g is increasing the impedance matching can be greatly improved.

The results show that changing the size of ground plane in all four figures (Fig. 3-Fig. 6) has a direct effect on its area as the area was nearly around 300 mm^2, bandwidth of the antenna were almost one and the same.

The geometry of antenna with four grounded semi-triangles metallic strips is shown in Fig. 7. Two circles show in this figure specify the location of circular grounded strip.

Fig. 8 shows the effect of the antenna using circular grounded strip as shown in Fig. 1. (antenna I) in comparison with the antenna using four semi-triangle grounded strip (without circular grounded strip) as shown in Fig. 7. at L_s=18.8 mm (antenna II). It can be seen that in the case of antenna I, circular grounded strip on ground plane cause to achieve a broadband width.

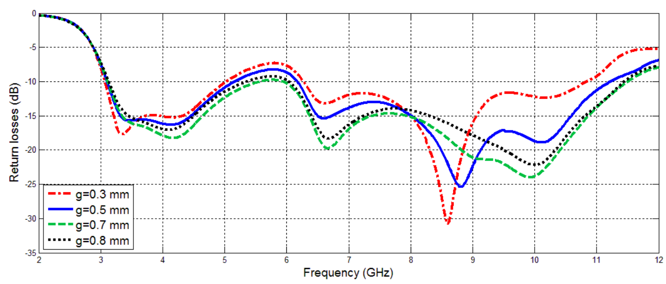

Fig. 6. Simulated reflection coefficients of the proposed antenna with different value of gap distance (g) with a fixed values of P_1=4.4, P_2=4.5, L=18.8 and T_2=4.8 (Units are in mm).

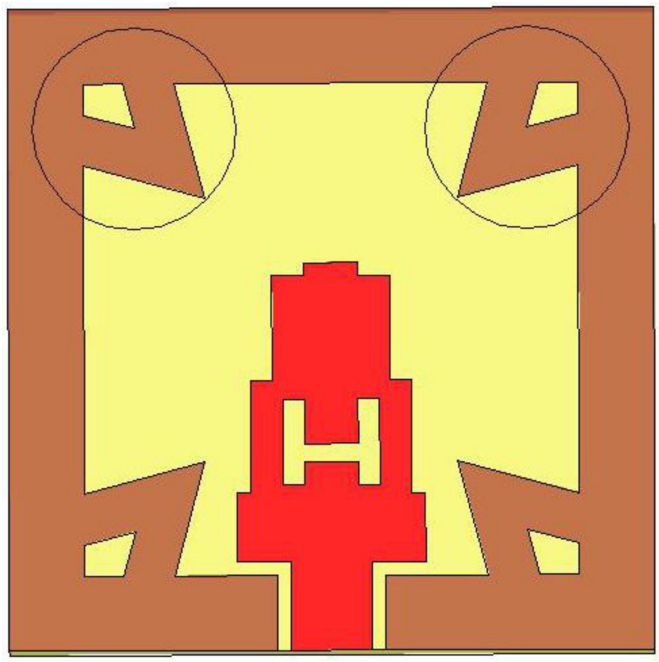

Fig. 7. Geometry of the antenna with four semi-triangles metallic strip in comparison of proposed antenna with two circular grounded strip.

IV. Experimental Results

The prototype of the proposed antenna is shown in Fig. 9. The measured reflection coefficients of the proposed antenna (L_s=18.8 mm, P_1=4.4 mm, P_2=4.8 mm, A=3.7 mm, T_2=4.76 mm) using an hp 8510 network analyzer in comparison with simulated reflection coefficients is shown in Fig. 10. The antenna bandwidth covers the range of 3 GHz to 11 GHz with the band-notched function in wireless LAN frequency band.

The measured peak antenna gain is shown in Fig. 11. Clearly, the peak antenna gain is varied from about 2 dBi to 3.5 dBi across the UWB operating frequencies (3 to 11GHz). The maximum gain for the antenna is 3.7 dBi at 11 GHz.

The far-field radiation patterns in the xz- and yz-planes at four different frequencies of 4, 7, 8 and 10 GHz for this obtained CPW-fed monopole antenna were also measured and shown in Fig. 12. The patterns in the x-y plane are all nearly omni-directional, and those in the y-z plane, as expected, are all very monopole-like and become more directional with the increase of frequency.

Also, the values of cross-polarization in the direction of

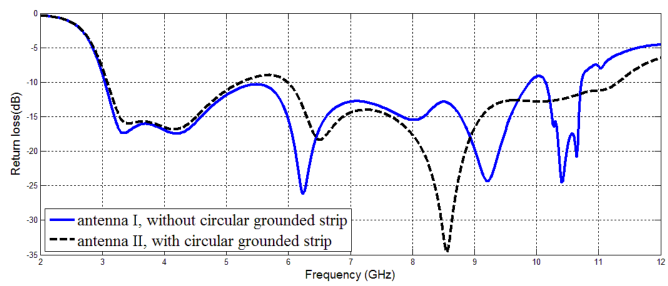

Fig. 8. Simulated reflection coefficient of the antenna I and antenna II, with L_s=18.8.

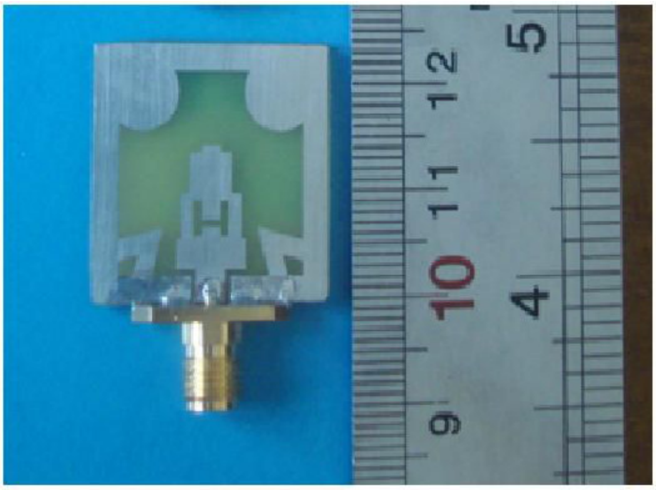

Fig. 9. Prototype of the proposed antenna.

the maximum radiation pattern towards the co-polarization are nearly -20 dB. Furthermore the antenna has stable radiation patterns over the UWB and Good agreements are obtained between the measurement and simulation results.

The simulated current distribution of the proposed antenna at 5.45 GHz is shown in Fig. 13. It reveals that the currents mainly concentrate over the area of H-shaped slot.

By etching an H-shaped slot in the radiating patch of antenna I, a frequency band notch is created. In general terms, the design concept of the notch function is to adjust the total length of the H-shaped slot to be approximately lower than half-wavelength at the desired notched frequency. The current distribution flows around the H-shaped slot. In this case, interference for the excited surface currents in the antenna causes the antenna to show large reflection and band-reject characteristic at that frequency.

V. Conclusion

In this paper, a compact notch-band CPW-fed monopole antenna has been presented. This antenna is fed by staircase CPW line. Two semi-triangles metallic strips are located at down corner and two circular metallic strips are located at up corner of square slot. By using two circular grounded strip the impedance matching in high frequency band can be improved. Proposed antenna is covered frequency bandwidth of 3.1-5 GHz and 6.1-10.6 GHz, also good radiation characteristics are obtained from 3.1 GHz to 10.6 GHz. The proposed antenna is designed on FR4 substrate and the dimension of the antenna is reduced significantly (24×24 mm^2). The size reduction is about 20% compared with [7]. The measured maximum peak antenna gain at 10.5 GHz is 11.3 dBi. Therefore, the proposed antenna is suitable for UWB applications simultaneously without interference to nearby communication system such as the wireless local area network (WLAN) applications.

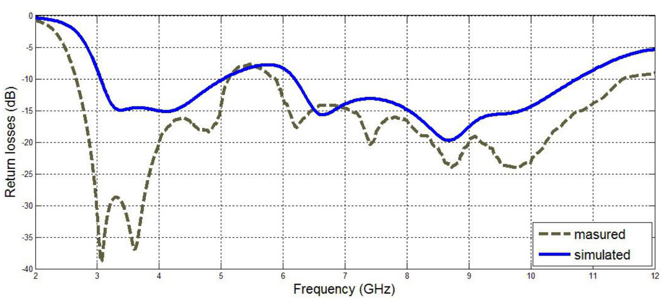

Fig. 10. Simulated and measured reflection coefficients of the proposed antenna with values P_1=4.4mm, P_2=4.8mm and L_s=18.8mm.

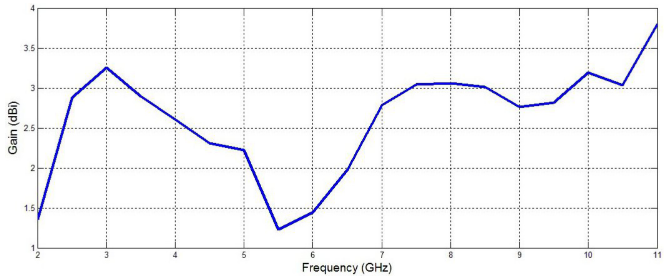

Fig. 11. Measured gain of CPW-fed monopole antenna.

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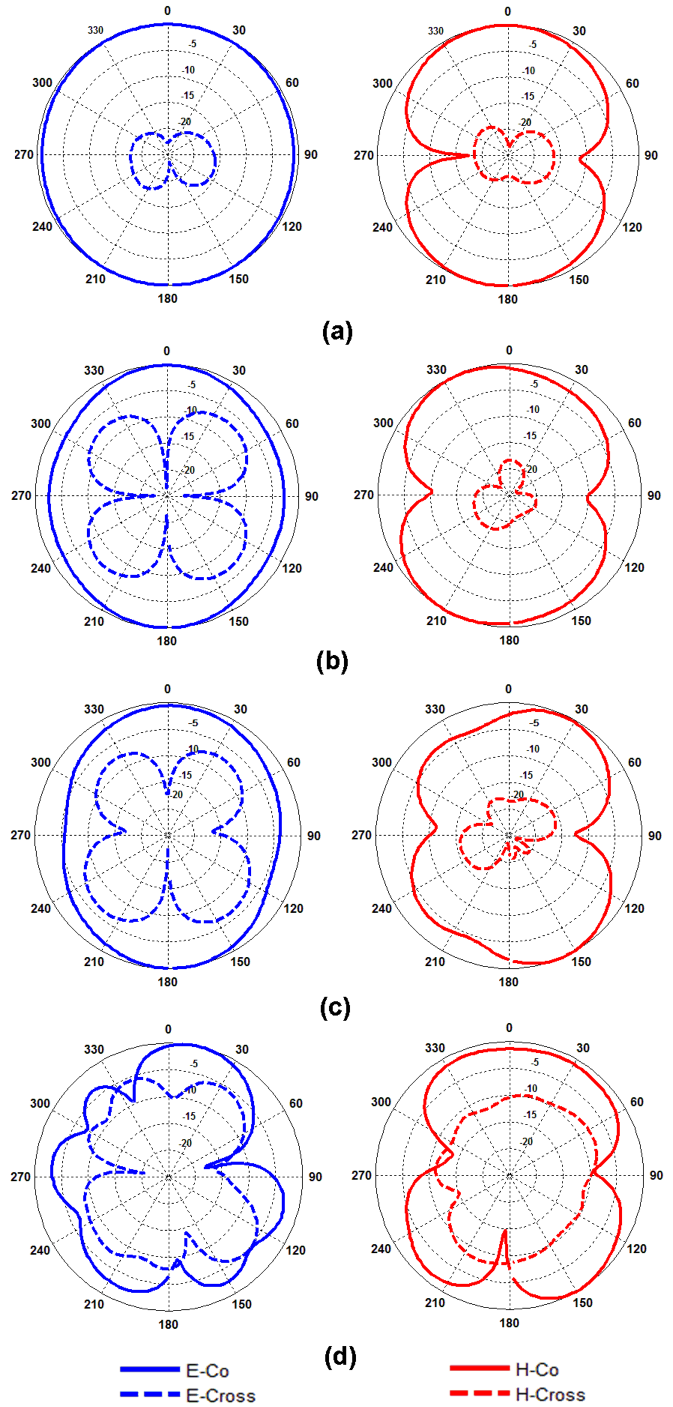

Fig. 12. Measured far field radiation patterns of the proposed antenna at: (a) 4 GHz, (b) 7 GHz (c), 8 GHz, (d) 10 GHz.

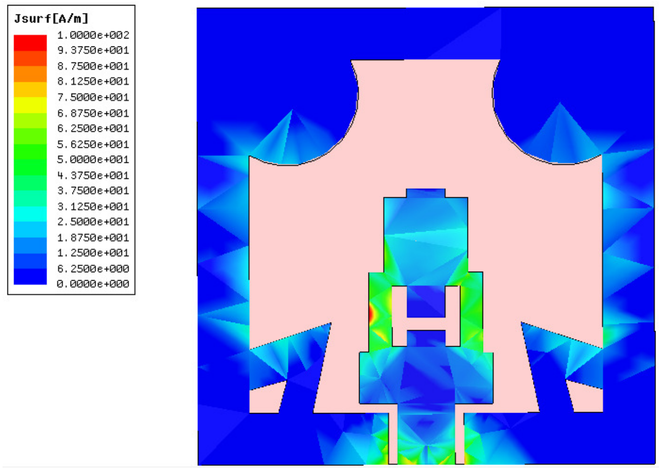

Fig. 13. Simulated current distribution of the proposed antenna at 5.45 GHz.