Novel Compact Circular Monopole Antenna with Defected Ground Structure for RFID, WLAN, Bluetooth and C-BAND Applications

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Abstract: This article proposes a compact planar circular monopole antenna with defected ground structure for RFID, WLAN, BLUETOOTH and C-BAND applications. The size of the proposed UWB antenna is 30 x 35 x 1.6 mm^3.The proposed antenna is excited by employing a circular radiating patch on one side of substrate with a rectangular slot loaded partial ground plane. By properly etching the slot placed at the centre of ground plane, wide operating bandwidth (3.26-10.98 GHz) will be obtained. So as to realize multi resonance behaviour the antenna includes a pair of symmetrical C-shaped slot embedded on the ground plane. With this design the proposed antenna blocks the interfering signals from WiMAX (3.3-3.6GHz) and X band uplink (7.9-8.45 GHz) applications. Simulated results show that the proposed circular monopole antenna features high gain, good surface current distribution, multi band behaviour and agreeable radiation characteristics within the achieved impedance bandwidth.
Keywords: Band-notched, Monopole antenna, Ultra wide band (UWB), C-shaped slots, Defected ground structure (DGS)

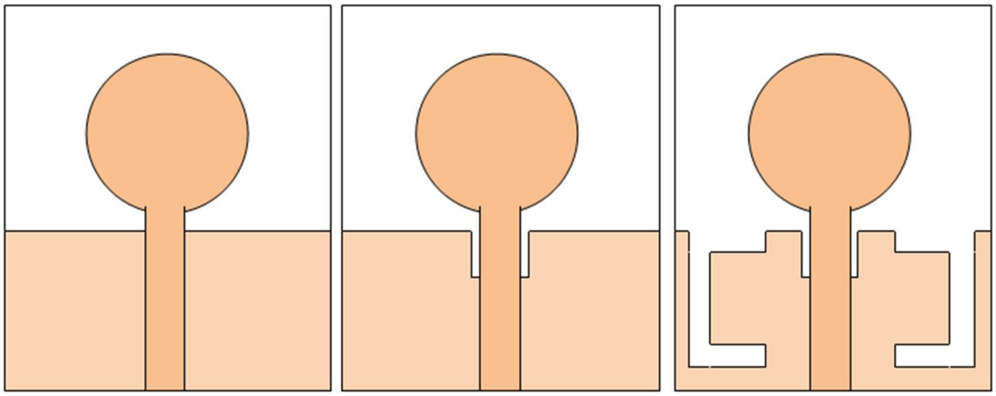
I. INTRODUCTION

Recently UWB systems have been widely utilized in several applications because of its several benefits such as low cost and complexity, high potency and bandwidth, defiant to rigorous multipath and jamming etc. From the time once the 3.1–10.6 GHz frequency range was assigned for ultra-wideband (UWB) applications by federal communication commission (FCC) in 2002, these systems attracted a lot of attention in communication systems, radars, imaging systems etc [1].UWB technology gaining popularity owing to its exceptional features like stable omnidirectional radiation pattern, good impedance matching and enhanced data rate. Nevertheless, there is an issue of a feasible electromagnetic interference, as over the assigned wide band of the UWB system. Some narrow bands such as WiMAX operating in 3.2–3.6 GHz, IEEE 802.11a WLAN operating in 5.15–5.825 GHz and X band satellite communication systems operating in 7.25–8.45 GHz can create interference within the UWB frequency range.

UWB system needed a single antenna to cover multiple frequency bands, gradually require a compact single antenna operating on multiple radiation bands along with UWB range is extensively rising because of its small size, large channel capacity and stress-free integration with different wireless standards. To get multi band characteristics in printed monopole antenna, several techniques are reported. Firstly patch antenna is designed to cover the desired wide bandwidth, and then the unwanted bands are notched using one of the band notching technique. In [1], Split ring resonator (SRR) loaded on the back side of CPW fed circular monopole antenna for achieving band notch performance while in [2, 3, 4] different type of slots(circle like slot, L shaped slits and S shaped slot) are etched to attain the desired band notch characteristics. A pair of stubs is locating to create band rejection characteristics in [5].So notches are should be introduced to generate the multi band behaviour. But the size of antenna will increase owing to lower frequency design of an antenna.

In [6, 7] small-size antenna are often designed to cover the highest frequency band, and for generating lower frequency bands, resonating strips are used. To cover antennas lower and upper bands, triangular monopole and U shaped strip are used in [6].Here electromagnetic coupling exists between both the monopoles to generate the upper band. Whereas in [7] symmetrical bevel slots are formed on the lower side of radiating patch and inverted U slot wont to improve the impedance matching. Defected ground structures (DGS) also has been used for multiband and broadband behaviour. In [8, 9] different dimensions of the defect are varied for achieving desired performance.

This paper proposes a novel design of circular patch antenna with symmetrical C-shaped DGS for multiband characteristics. HFSS (High Frequency Structured Simulator) tool is used for design and analysis of the proposed antenna. This tool is more often wont to the analysis of RF and microwave circuits. The proposed design is fed with 50 Ω micro strip line feeding. The antenna prototype with a compact overall size of 30 x 35 x 1.6 mm^3 achieves high gain, good impedance matching, and stable radiation patterns. The design process and parameters are explained in section II and Section III describes simulation of proposed antenna. Section IV concludes the paper.

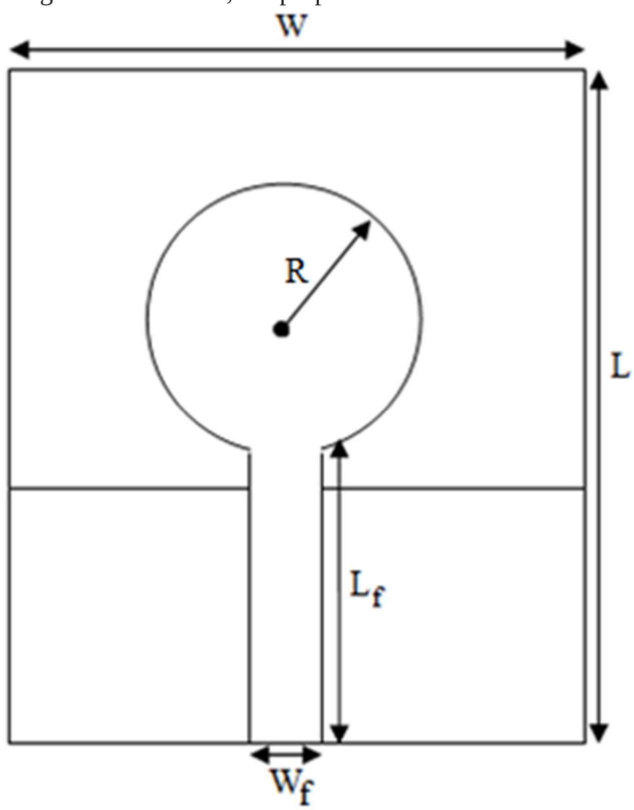


(a) (b) (c)

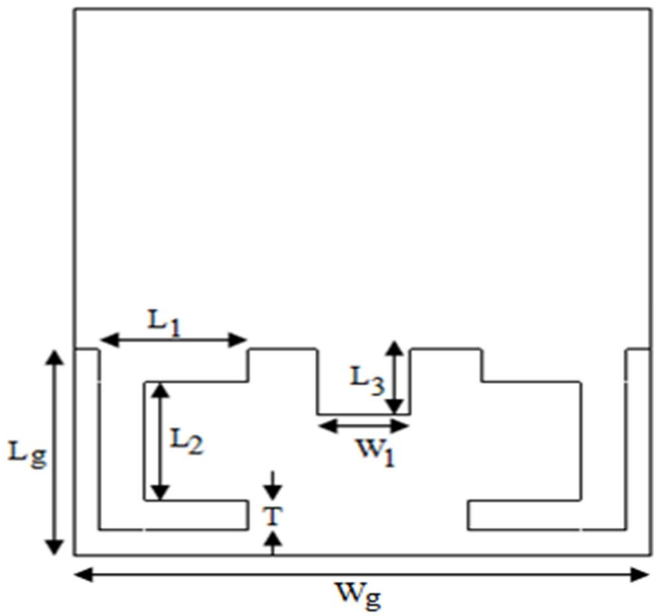
Fig. 1 Structure of the proposed antenna (a) Ordinary circular monopole antenna (b) Antenna with rectangular notch on ground plane (c) proposed antenna

II. ANTENNA CONFIGURATION

Fig. 1 shows the various steps used in designing of the proposed antenna. The geometry of the proposed design as depicted in Fig.2, consists of a circular patch mounted on the top layer of 1.6mm thick FR4 dielectric substrate which has a dielectric constant of 4.4 and tan δ=0.02.Even as the defected partial ground plane placed on the bottom of substrate. The overall size of antenna is 30x35 mm^2.Symmetrical C-shaped slots on each side of feed line and a rectangular notch in the middle of partial ground plane etched, which would lead to good impedance matching. In order to attain the large impedance bandwidth circular monopole was chosen as the radiating element. The proposed circular monopole antenna is fed by 50 Ω micro strip line feed. The width of the micro strip feed line is fixed at 3.4 mm. For better signal transmission, the proposed antenna is connected to SMA connector.



(a)



(b)

Fig.2 Geometry of Proposed Antenna (a) Top View (b) Bottom View

First of all, optimization is performed on the dimensions of circular monopole antenna to obtain the desired UWB frequency. Thereafter, dimensional analysis of proposed defected ground structure is done. Here multiband behaviour generated by the first method (cutting slots).Incorporating slots on the ground plane is effective than other techniques reported for getting multiband characteristics. Moreover compactness is also achieved by using this technique. Firstly, ordinary circular patch antenna with partial ground plane designed. For achieving UWB performance, rectangular slot inserted in the centre of partial ground plane, after that symmetrical C shaped slots etching off the ground plane for rejection of certain frequency bands. Final values of the proposed antenna design are given in Table 1.

Table 1. Dimensions of the proposed antenna

Parameters	Dimensions(mm)
Substrate	W= 30 L= 35 h= 1.6
Circular patch	R= 7
Defected ground	W_g = 30 L_g = 13
Symmetrical C-slots	L_1 = 7 L_2 = 8 T = 2
Feed line	L_f = 14 W_f = 3.4
Rectangular slot	L_3 =3 W_1=4

III. RESULTS AND DISCUSSION

In this Section, the circular monopole antenna with various design parameters were constructed, and the numerical and experimental results of the gain, return loss and radiation characteristics are presented and discussed. The simulated results are achieved using the Ansoft simulation software high frequency structure simulator (HFSS). VSWR characteristics for ordinary circular monopole antenna (Fig.1 (a)), antenna with rectangular notch on ground plane (Fig.1 (b)) and proposed antenna (Fig.1(c)) are compared in Fig.3.

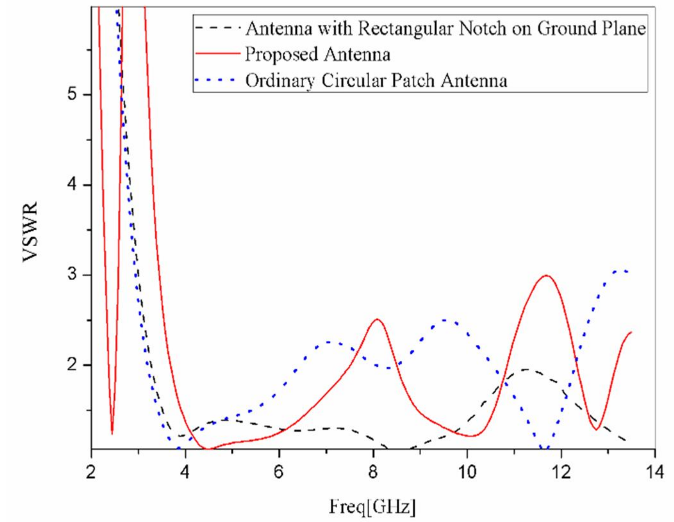


Fig. 3 Simulated VSWR characteristics for various antenna structures (shown in Fig. 1)

Fig.3 illustrated that the ordinary circular monopole antenna can provide two resonant radiation bands at 3.82 and 11.67 GHz. To achieve the UWB coverage (3.1-10.6 GHz), a rectangular slot etched in the ground plane. The bandwidth is significantly affected by this rectangular slot because creating slots in the ground plane provide an additional current path. It is observed that by embedding rectangular slot in the partial ground plane, impedance bandwidth from 3.26 to 10.98GHz achieves. In addition, by inserting symmetrical C-shaped slots on both side of feed line, the multi resonance behaviour achieved. According to the simulated results, it can be found that the proposed circular monopole antenna with DGS can effectively cover four separated impedance bandwidth of 170 MHz (2.34-2.51GHz), 3700 MHz (3.7-7.4 GHz), 2170 MHz (8.53-10.7GHz) and 800MHz (12.3-13.1GHz) which can well satisfy the RFID bands 2.4/6.8 GHz, WLAN bands 2.4/5.2/5.8 GHz, Bluetooth 2.4 GHz and C band (3.7-6.42 GHz).

Fig.4 shows the variation of return loss of the proposed antenna according to the frequency. As depicted in Fig.4 band elimination notches are also to be introduced by the symmetrical C shaped slot loaded ground plane. So the proposed antenna reduces the interference from WiMAX (3.3-3.6 GHz) and X band uplink (7.9-8.4 GHz).The variation of peak gain vs. Freq. shown in Fig.5.It can be seen from the fig.5 gain falls sharply in the notch bands because at the notch bands most of radiated power is reflected back to the antenna. While for the rest of the bands it remains stable.

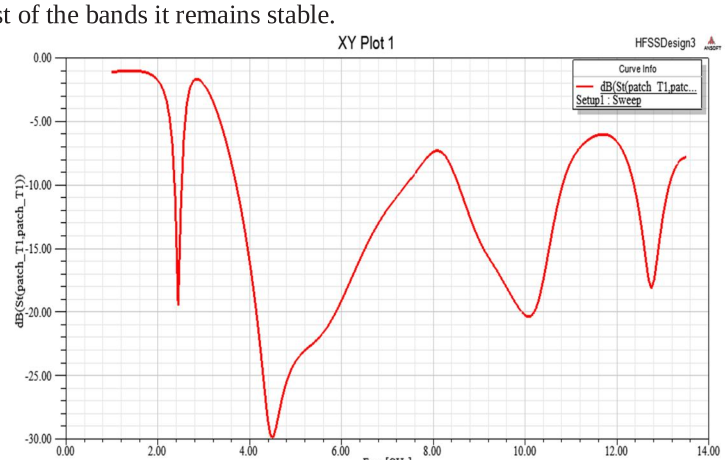


Fig. 4 Variation of return loss with frequency of the proposed antenna

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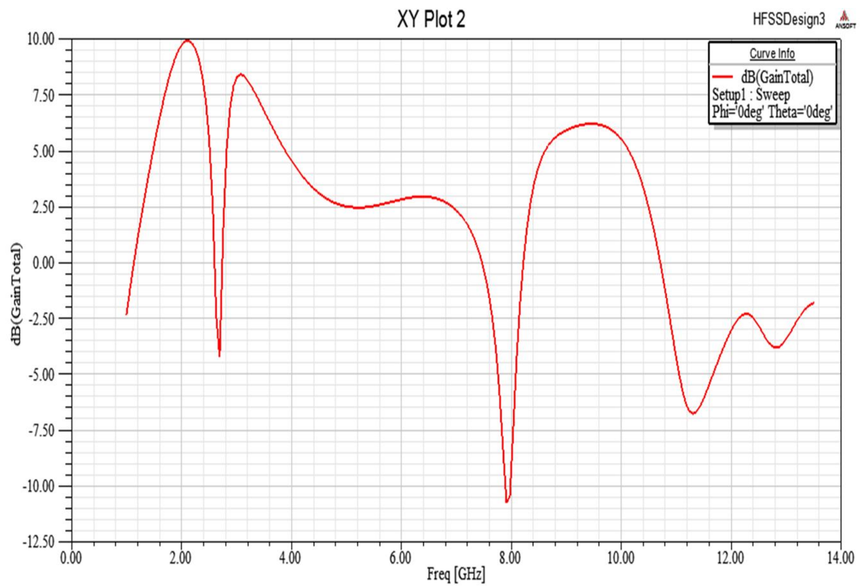
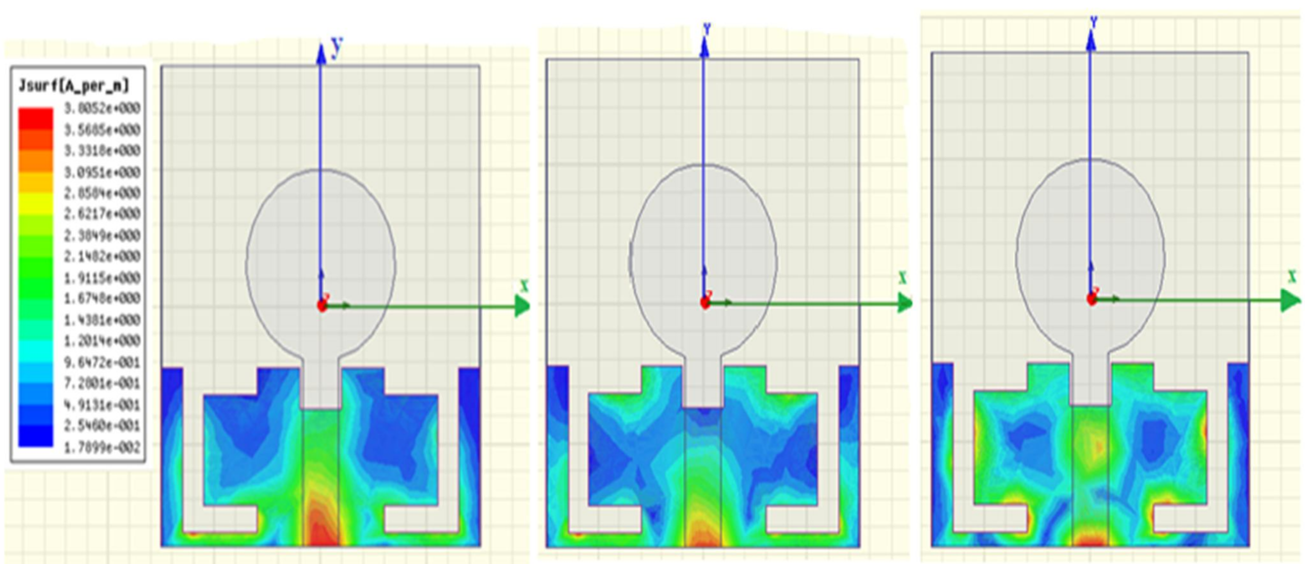


Fig. 5 Variation of peak gain with frequency of the proposed antenna

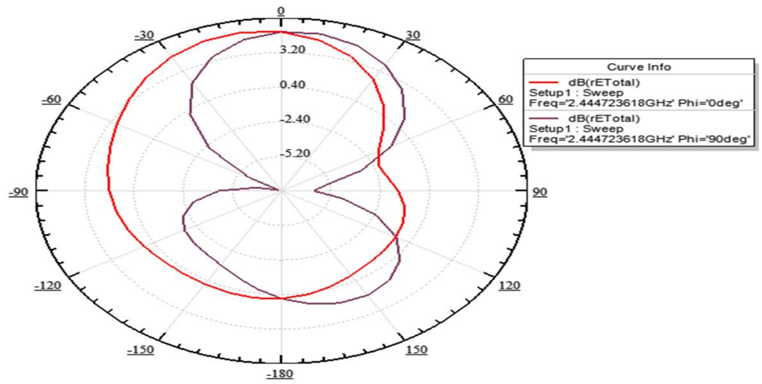


(a) (b) (c)

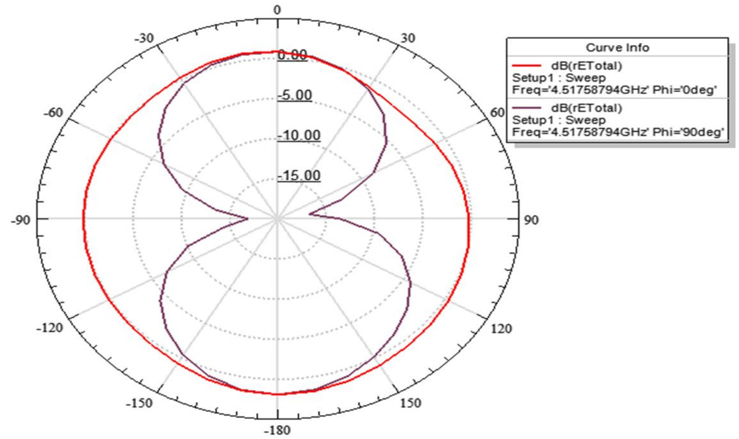
Fig.6 Surface current distributions at different frequencies (a) 2.44 GHz (b) 4.51GHz (c) 10.10 GHz

Fig.6 illustrates the simulated surface current distribution at three different frequencies, 2.44 GHz, 4.51 GHz and 10.10 GHz of operation. From the figure, it is observed that three different resonance modes can be excited at three different positions of the proposed antenna. As seen from the Fig.6 (a), at 2.44 GHz the strong current density concentrated over the feed line and the lower edge of the partial ground plane. Fig.6 (b) illustrated that at 4.51 GHz, surface current mainly distributed along the upper edge and the lower edge of ground plane. Whereas Fig.6(c) reveals that as the freq. increases from (4.51-10.10 GHz), strong current distribution achieved along the feed line and the interior edge of symmetrical C slot loaded defected ground plane.

Fig. 7 indicates the simulated far field radiation patterns in E-plane (yz- plane) and H-plane (xz-plane) at sampling frequencies of 2.44, 4.51, and 6.02 GHz, respectively. Fig. depicted that radiation pattern in H –plane is stable and omnidirectional for 4.51 and 6.02 GHz frequency and nearly omnidirectional for 2.44 GHz. Even as radiation pattern in E-plane for all three frequencies is dipole like pattern. It is observed from the figure as the proposed antenna structure possesses symmetry so that radiation patterns are in symmetry with respect to the antenna axis ($\theta = 0^o$). It can be seen that the achieved radiation patterns are stable throughout the frequency band of operation.



(a)



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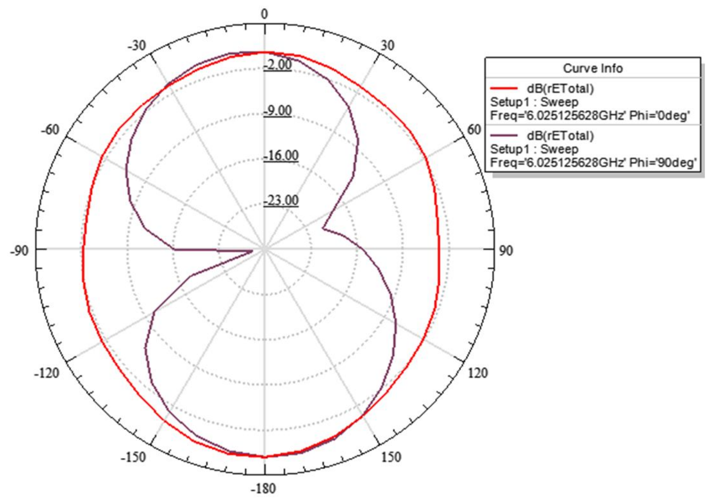

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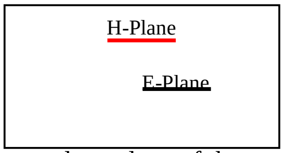

Fig.7 Simulated radiation patterns for *x-y* plane and *x-z* plane of the proposed antenna for three different frequencies (a) 2.44 GHz (b) 4.51 GHz (c) 6.02 GHz.

IV. CONCLUSION

In this letter, a compact printed microstrip line fed circular monopole antenna with defected ground structure has been presented and investigated in detail. It is observed that by inserting a pair of symmetrical C shaped slot in both sides of feed line and a rectangular notch at the centre of ground plane with proper dimensions, multi band behaviour achieved. This type of antenna can be easily integrated with the WLAN, Bluetooth, and C-band and also useful for RFID system. Furthermore, properties such as good omnidirectional coverage, high gain and stable radiation characteristics, indicate that the proposed antenna is well suitable for UWB communication applications and prevents interference with the X band uplink and WiMAX systems.

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